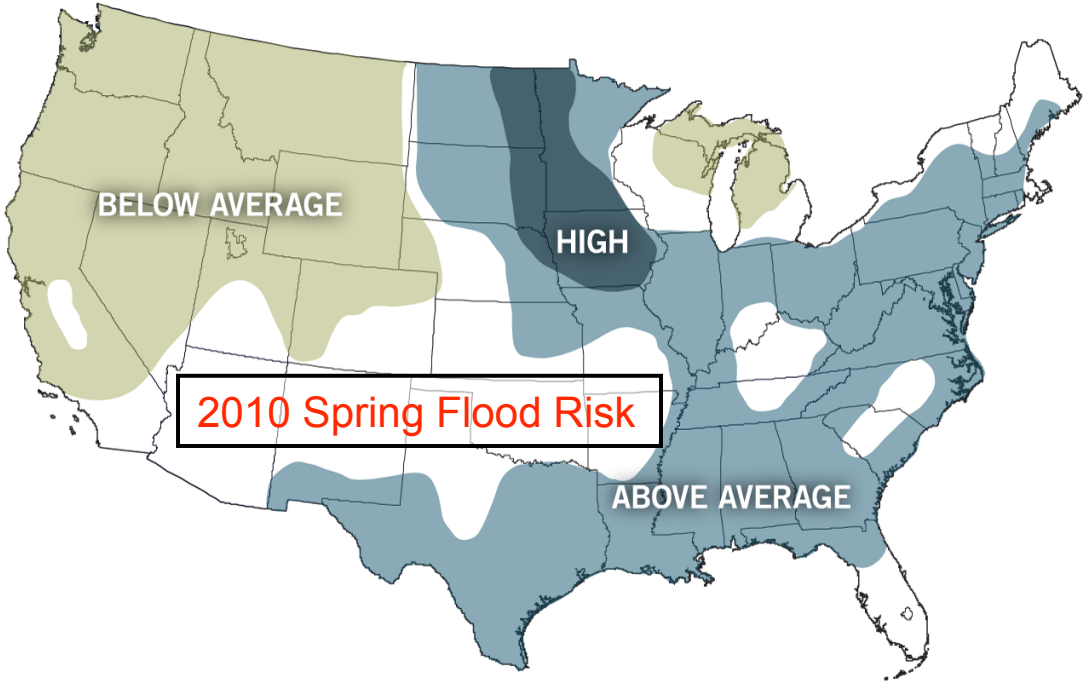
NOAA's Hydrometeorology Testbed (HMT)

"Tools for Water in a Changing Climate"



Tim Schneider,
HMT Project Manager
NOAA-ESRL, Boulder, CO

http://www.climatewatch.noaa.gov/2010/images/flood-risk-forecasted-for-one-third-of-u-s

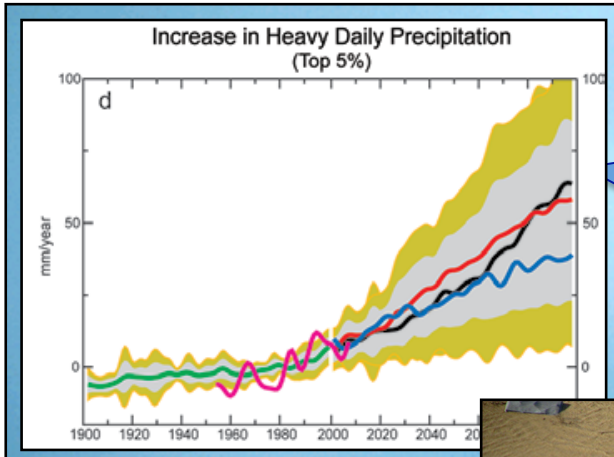
Outline

I. Brief Overview of HMT

II. Select Results

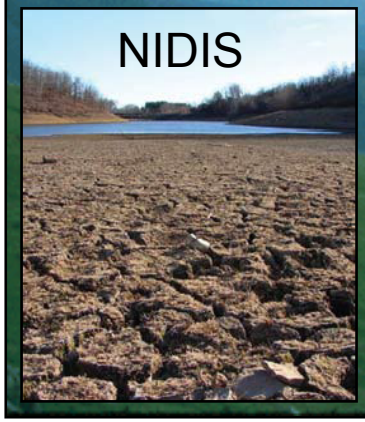
- Intangibles (programmatic developments)
- Research
- Innovation & Prototyping (Operations)

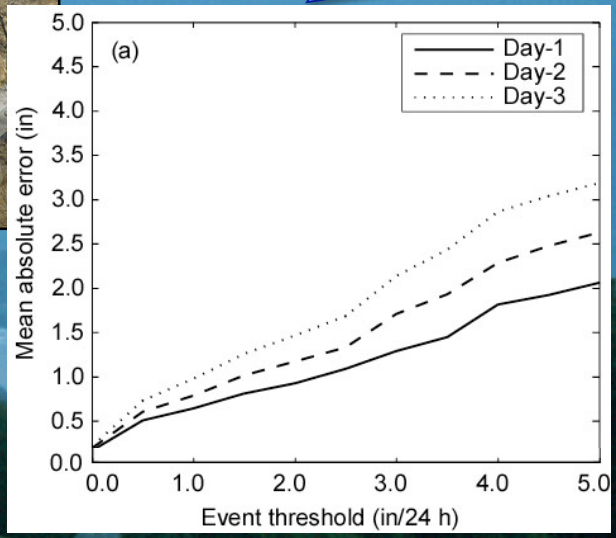
Water Extremes in a Changing Climate



Problem

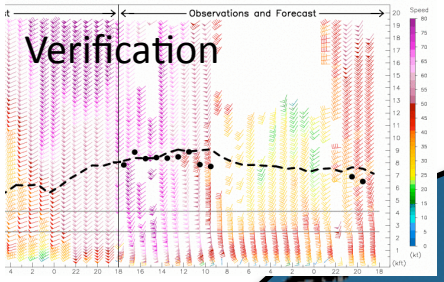
Threat

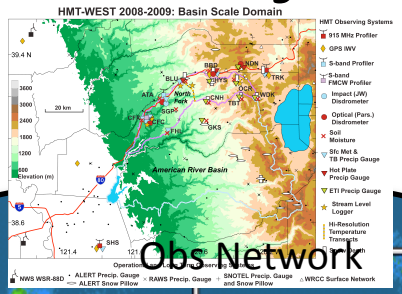


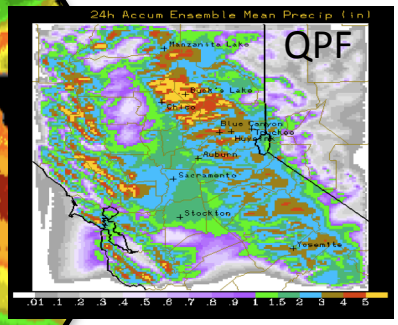


Challenge

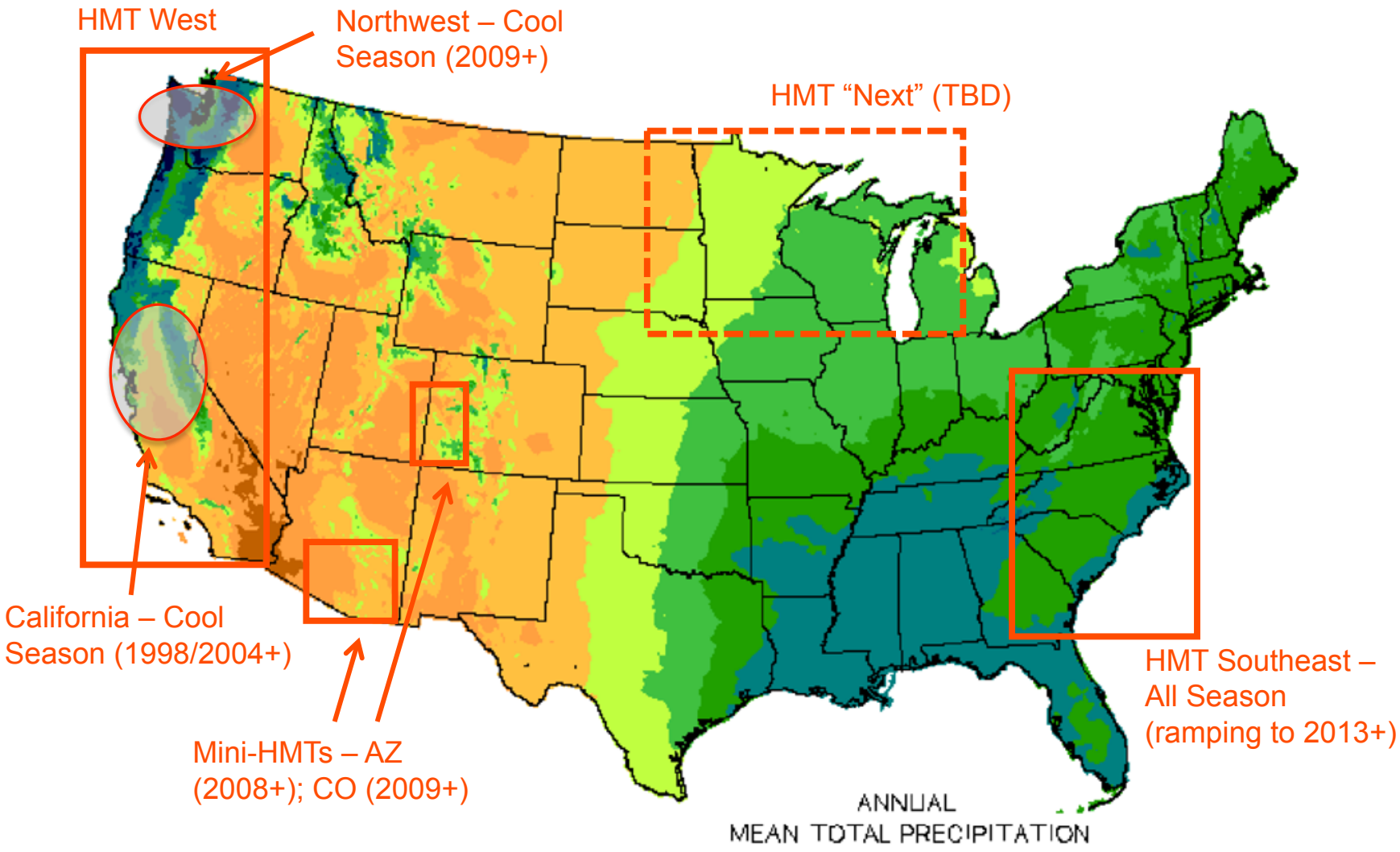
Response: HMT's Major Activity Areas



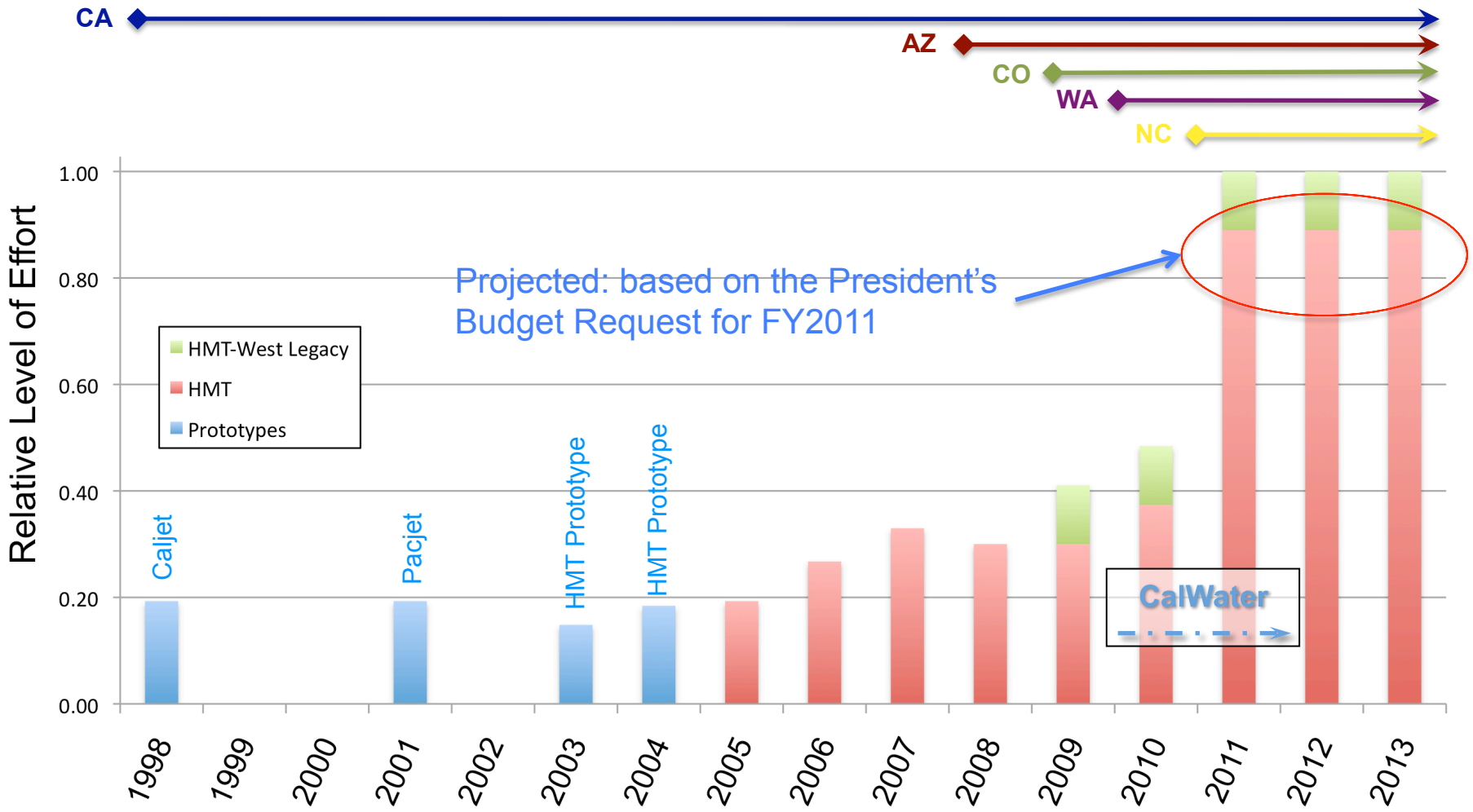




A National Testbed Strategy



Timeline & Overall Effort



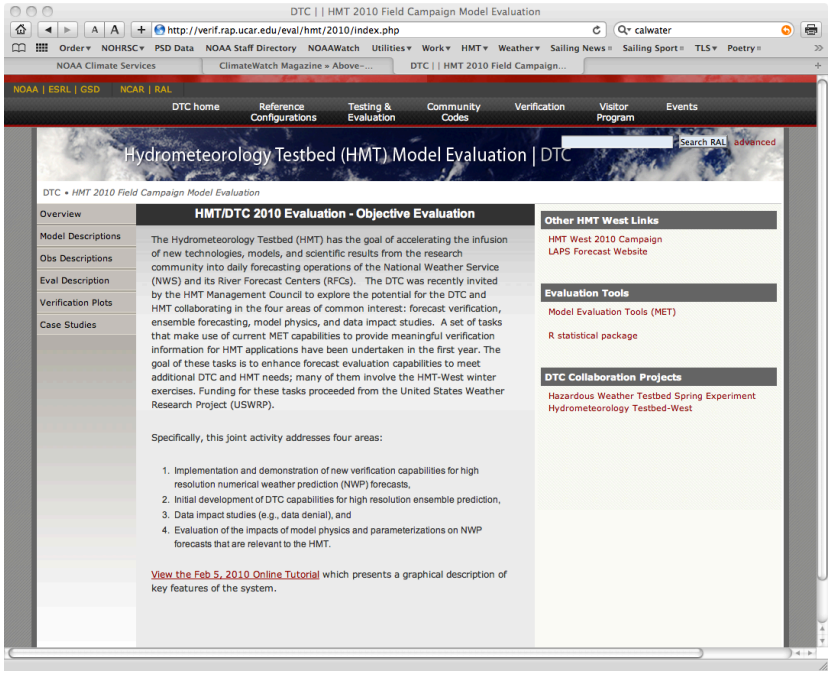
Intangibles

- Two new hires:
  - Lynn Johnson; to help build the hydrology program
  - Rob Cifelli; Field Operations Coordinator & QPE in complex terrain
    - See: "Quantitative Precipitation Estimation in Colorado & Oklahoma Storms using X and S-band Dual Polarimetric Radar Data – *V. Chandrasekar (CSU)*; Day 1, PM

- Improved coordination with HPC
  - Two hires: Faye Barthold and 1 planned (joint)
  - See: *"HMT at the NCEP Hydrometeorological Prediction Center"*
  - Faye Barthold (NCEP); Day1-PM
- CSTAR
  - See: "*Collaborative Science Technology & Applied Research"* – Sam Contorno (NWS); Day1-AM
  - Two proposals funded 2007-2010:
    - See: *"CSTAR Activities at the University of Utah"* – John Horel (University of Utah); Day1-PM
    - See: *"Mechanisms for Predecessor Rain Events Ahead of Tropical Cyclones"* – Ben Moore (SUNY) ; Day1-PM
  - Two proposals funded 2010-2013:
    - See: *"CSTAR Activities at SUNY Stony Brook"* – Brian Colle (SUNY Stony Brook) ; Day1-PM
    - See: *"Collaborative Strategies and Upcoming CSTAR Activities in the Southeastern U.S."* – Gary Lackmann (North Carolina State University) ; Day1-PM

Intangibles, cont.

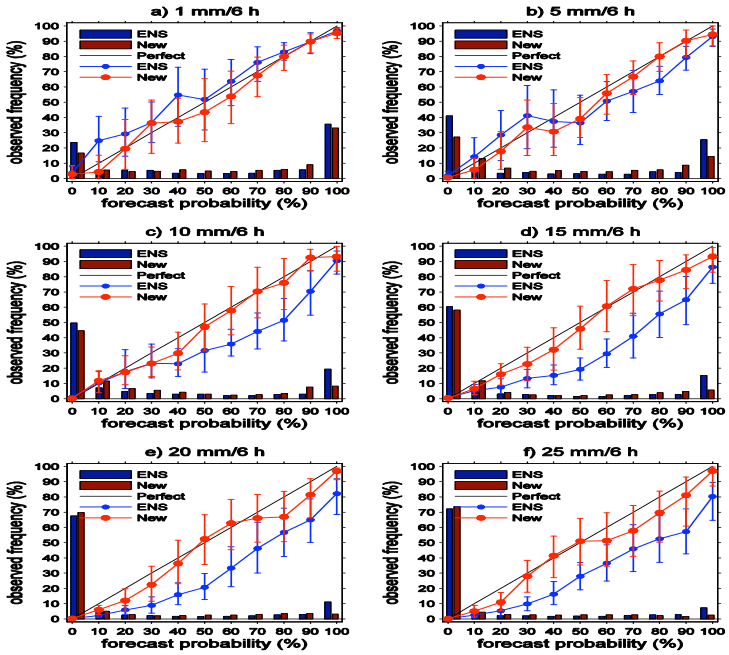
- CalWater
  - Two major scientific thrusts to determine the impact of aerosols on precipitation and the role of ARs in water supply and flooding



- GPM: Coordinated GV efforts (planned)
  - HMT-SE in 2013
  - HMT-W/NW in 2014
- HMT-DTC Collaboration on QPF verification
  - See: *"Developmental Testbed Center"* – Bill Kuo (NCAR); Day 1, AM
  - See: *"DTC- HMT Collaboration with USWRP: Evaluation of QPF during the HMT-West Winter Exercise"* – Ed Tollerud (ESRL); Day 1, PM
  - See: "*MODE Analyses of Integrated Water Vapor and Integrated Vapor Transport Fields – Wallace Clark (ESRL)*; Day 1, PM
- THORPEX
  - See: *"THORPEX Overview & Connection to Testbeds" – Tom Hamill (ESRL)* ; Day2-PM

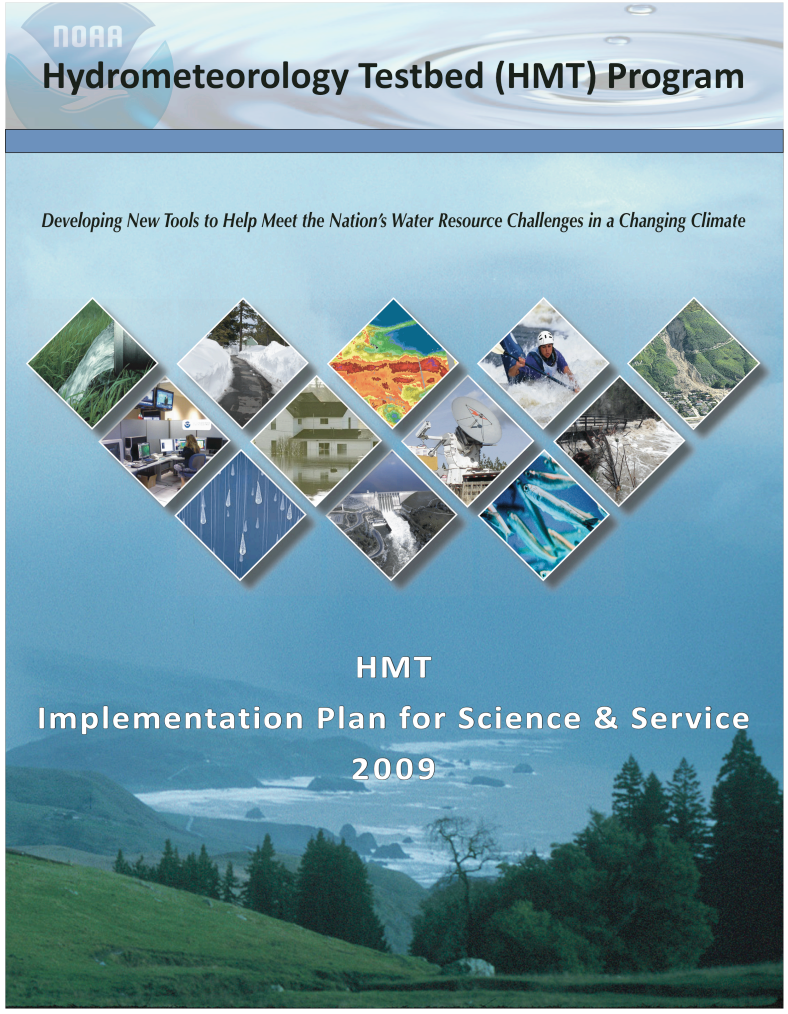
Research

- Impacts of AR's and flooding in Western WA
  - Paul Neiman & Larry Schick, submitted
  - See: *"Flooding in Western Washington - The Connection to Atmospheric Rivers"* – Paul Neiman (ESRL); Day 1, PM
- Hi-resolution modeling
  - See: "*Ensemble Prediction System Development for HMT Application"* – Isidora Jankov (ESRL) ; Day 1, AM
  - See: "*Statistics for HMT-West Ensemble Forecasts during the Winter 2009-2010"* – Huiling Yuan (ESRL); Day 1, AM
- Barrier Jet
  - Role in modulating precipitation along the front range of the Sierras



Research, cont.

- HMT Implementation Plan Completed (2009)
- Extensive (and growing) list of publications…



		HMT Major Activity Area					
Phenomena	Paper	QPE	QPF	SI	HA	V/ DST	DF
Atmospheric Rivers (8)	Bao'06		✓		✓	✓	
	Junker'09		✓			✓	
	Neiman'08a	✓	✓	✓	✓	✓	
	Neiman'08b	✓	✓	✓	✓	✓	
	Ralph'06		✓		✓	✓	
	Ralph'05a		✓			✓	
	Ralph'04		✓		✓	✓	
	Wick'08		✓		✓	✓	
Warm Rain Processes (4)	Kingsmill'06	✓	✓			✓	
	Martner'08	✓	✓		✓	✓	
	Neiman'05	✓	✓		✓	✓	
	White'03	✓	✓		✓	✓	
Orographic Effects (7)	Neiman'10	✓				✓	
	Neiman'06		✓				
	Neiman'04		✓			✓	
	Neiman'02		✓		✓	✓	
	Nuss'01		✓			✓	
	Smith'10		✓			✓	
	Ralph'03	✓	✓		✓	✓	
Observing Systems (15)	Dabberdt'05	✓	✓		✓	✓	
	Gourley'09	✓			✓	✓	
	Lundquist'09	✓		✓	✓		
	Lundquist'08a			✓	✓		
	Lundquist'08b			✓	✓		
	Martner'07	✓					
	Matrosov'10	✓		✓		✓	
	Matrosov'09	✓		✓			
	Matrosov'08	✓		✓		✓	
	Matrosov'07	✓		✓			
	Matrosov'05	✓				✓	
	Matrosov'04	✓		✓			
	Neiman'09		✓	✓	✓	✓	
	White'02			✓	✓	✓	
	White'00	✓		✓			
Precipitation Forecasting (6)	Jankov'09		✓			✓	
	Jankov'07		✓				
	Junker'08		✓			✓	
	Morss'07	✓	✓		✓	✓	
	Ralph'05b	✓	✓	✓	✓	✓	
	Yuan'08		✓				
Physical Processes (7)	Andrews'04		✓		✓		
	Coplen'08	✓					
	Jorgensen'03	✓	✓		✓		
	Persson'05		✓		✓	✓	
	Restrepo'08	✓				✓	✓
	Richiardone'09					✓	
	Wilczak'07					✓	

47 peer reviewed papers since 2000

<u>Appearing in Journals:</u>

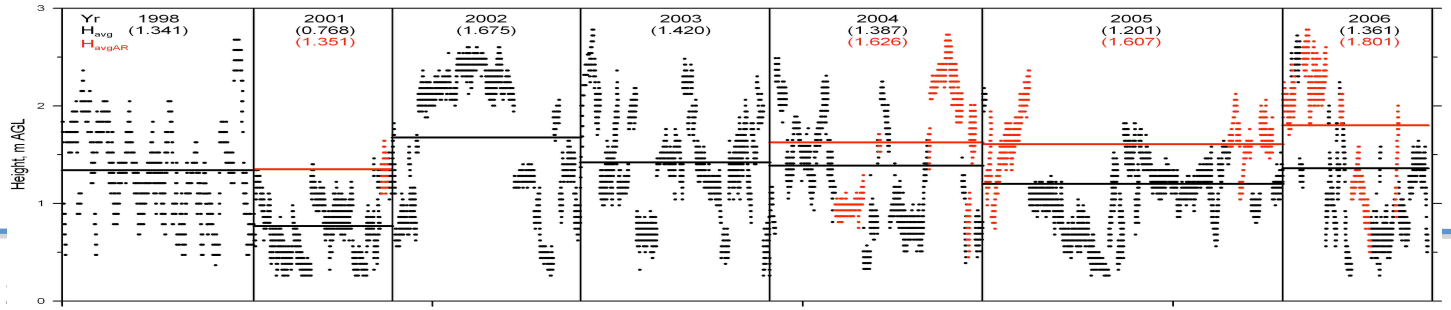
- Monthly Weather Review
- J. Hydrometeorology
- J. Atmos. & Oceanic Tech.
- Bull. Amer. Meteor. Soc.
- Geophys. Res. Let.
- *Proc. Institution of Civil Engineers* – Water Resource Res.
- Weather & Forecasting
- IEEE Trans. on Geosci. & Rem. Sens.
- J. Appl. Meteor. & Climatology
- J. Climate
- Nonlin. Proc. in Geophys.
- Prog. in Oceanography
- Water Management

<u>Lead authors represent:</u>

- NOAA ESRL PSD
- NOAA ESRL GSD
- NOAA NSSL
- NOAA NWS NCEP
- NCAR/Societal Impacts Program
- USGS
- CIRES/University of Colorado
- CIRA/Colorado State University
- Naval Postgraduate School
- University of Washington
- Universit`a di Torino, Torino, Italy
- Contributing authors represent an additional 10 or more institutions

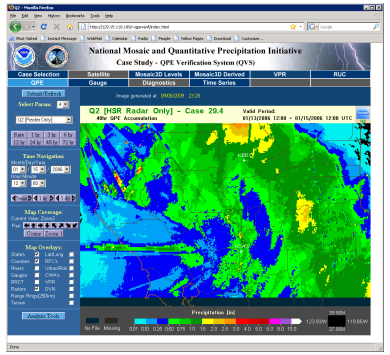
Innovation & Prototyping (Operations)

- New performance measures
  - River flood warning lead time; NWS-OHD/OCWWS – in process
  - Extreme QPF; Ralph et. al., in press
  - See: *"Assessment of Extreme QPF & Development of Regional Extreme Event Thresholds Using Data from HMT-2006 & COOP Observers"* – Ellen Sukovich (ESRL) ; Day 1, AM
  - Snow level; White et. al., in press
- HMT-West Legacy (EFREP)
  - Two snow level radars demonstrated in '09-'10
  - 2 soil moisture and 13 GPS-Met sites installed
  - See: *"The HMT-West Legacy Project: Current Status & Future Plans"* – Allen White (ESRL); Day 1, AM



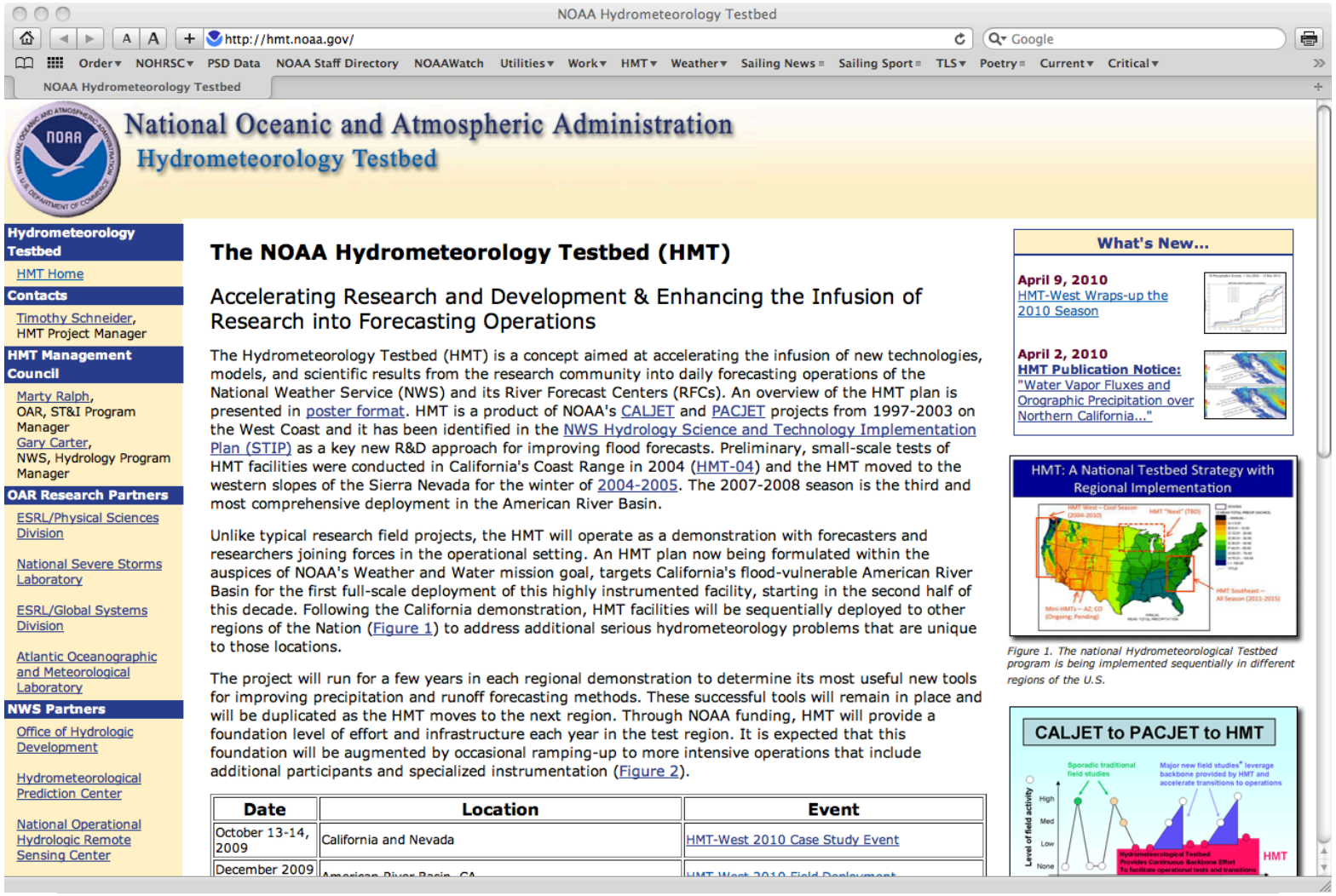
Innovation & Prototyping (Operations), cont.

- Improvements to NMQ/Q2 for QPE in complex terrain – national impact
  - Improved VPR algorithms and new Z-R relations
  - See: *"Development of Methodologies within a Testbed (per HMT) and their Subsequent Transition to a National System for Utilization by Operations"* – Ken Howard (NSSL); Day 1, PM



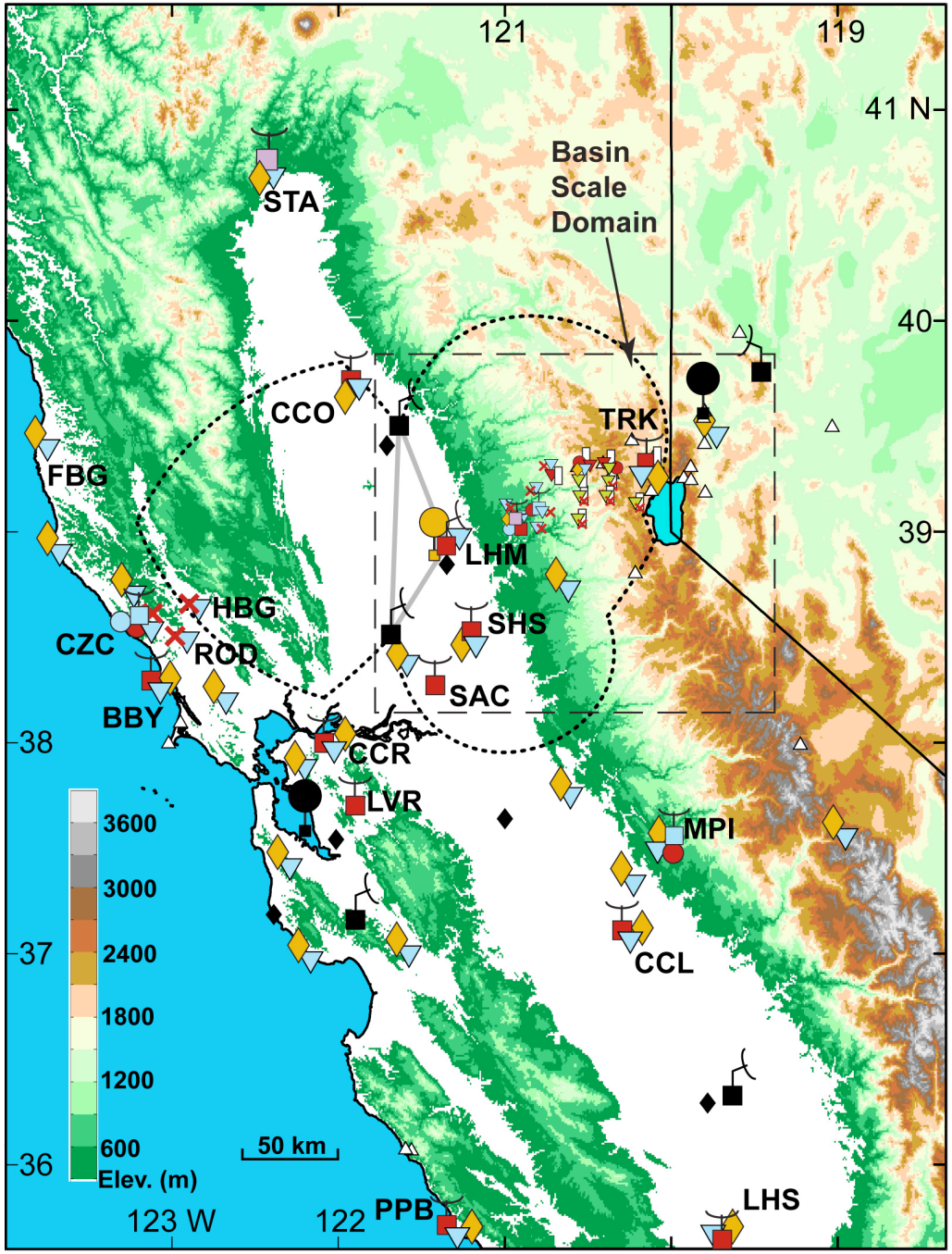
- Pacific-NW sites established (3+)
  - Westport: new mobile ARO deployed to apply lesson's learned in CA (Wx-Climate)
  - Rapid response to support Howard Hanson Dam issues (model + 2 observational sites);
  - Data has impacted HH Dam operations; heavy data use
  - Training in field, Fall '09

Coming Soon…


NOAA Hydrometeorology Testbed
http://hmt.noaa.gov/
National Oceanic and Atmospheric Administration
Hydrometeorology Testbed
Hydrometeorology Testbed
HMT Home
Contacts
Timothy Schneider, HMT Project Manager
HMT Management Council
Marty Ralph, OAR, ST&I Program Manager
Gary Carter, NWS, Hydrology Program Manager
OAR Research Partners
ESRL/Physical Sciences Division
National Severe Storms Laboratory
ESRL/Global Systems Division
Atlantic Oceanographic and Meteorological Laboratory
NWS Partners
Office of Hydrologic Development
Hydrometeorological Prediction Center
National Operational Hydrologic Remote Sensing Center
The NOAA Hydrometeorology Testbed (HMT)
Accelerating Research and Development & Enhancing the Infusion of Research into Forecasting Operations
The Hydrometeorology Testbed (HMT) is a concept aimed at accelerating the infusion of new technologies, models, and scientific results from the research community into daily forecasting operations of the National Weather Service (NWS) and its River Forecast Centers (RFCs). An overview of the HMT plan is presented in poster format. HMT is a product of NOAA's CALJET and PACJET projects from 1997-2003 on the West Coast and it has been identified in the NWS Hydrology Science and Technology Implementation Plan (STIP) as a key new R&D approach for improving flood forecasts. Preliminary, small-scale tests of HMT facilities were conducted in California's Coast Range in 2004 (HMT-04) and the HMT moved to the western slopes of the Sierra Nevada for the winter of 2004-2005. The 2007-2008 season is the third and most comprehensive deployment in the American River Basin.
Unlike typical research field projects, the HMT will operate as a demonstration with forecasters and researchers joining forces in the operational setting. An HMT plan now being formulated within the auspices of NOAA's Weather and Water mission goal, targets California's flood-vulnerable American River Basin for the first full-scale deployment of this highly instrumented facility, starting in the second half of this decade. Following the California demonstration, HMT facilities will be sequentially deployed to other regions of the Nation (Figure 1) to address additional serious hydrometeorology problems that are unique to those locations.
The project will run for a few years in each regional demonstration to determine its most useful new tools for improving precipitation and runoff forecasting methods. These successful tools will remain in place and will be duplicated as the HMT moves to the next region. Through NOAA funding, HMT will provide a foundation level of effort and infrastructure each year in the test region. It is expected that this foundation will be augmented by occasional ramping-up to more intensive operations that include additional participants and specialized instrumentation (Figure 2).
Date
Location
Event
October 13-14, 2009
California and Nevada
HMT-West 2010 Case Study Event
December 2009
What's New...
April 9, 2010
HMT-West Wraps-up the 2010 Season
April 2, 2010
HMT Publication Notice:
"Water Vapor Fluxes and Orographic Precipitation over Northern California..."
HMT: A National Testbed Strategy with Regional Implementation
Figure 1. The national Hydrometeorological Testbed program is being implemented sequentially in different regions of the U.S.
CALJET to PACJET to HMT
Sporadic traditional field studies
Major new field studies leverage backbone provided by HMT and accelerate transitions to operations
Level of field activity
High
Med
Low
None
HMT


Thank You!
http://hmt.noaa.gov/

HMT-WEST 2010: Regional Scale Domain



HMT Observing Systems

- ESRL C-band Doppler Radar (SKYWATER)
- 915 MHz Profiler
- GPS IWV
- S-band Profiler
- S-band FMCW Profiler
- Impact (JW) Disdrometer
- Optical (Parsivel) Disdrometer
- Soil Moisture
- Sfc Met & TB Precip Gauge
- Hot Plate Precip Gauge
- ETI Precip Gauge
- Snow Depth
- 3-D Multiple Doppler wind retrieval domain

BBY, CCO; CCL:
Since 1998

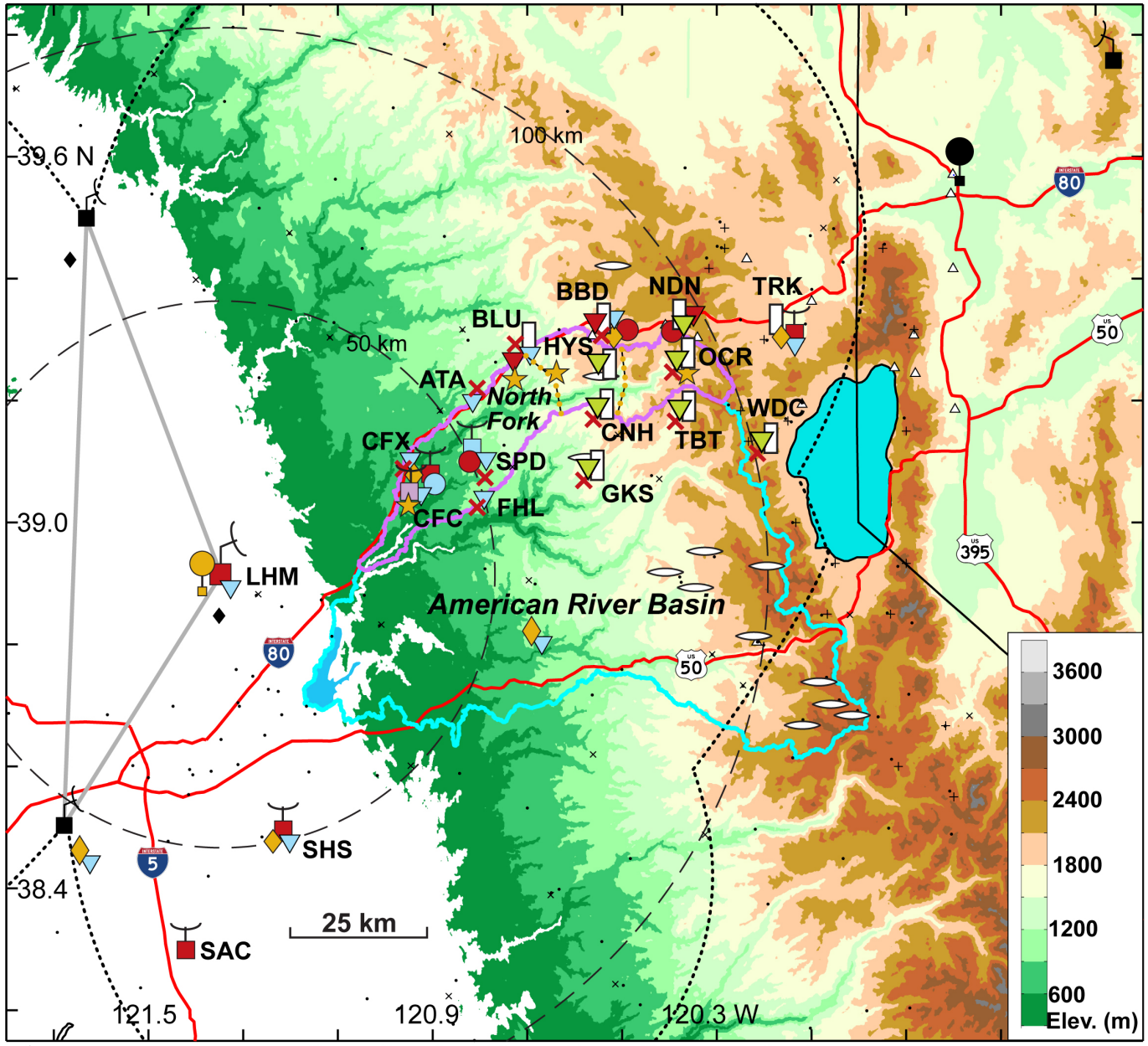
CZD:
Since 2001 (1998)

BLU:
Since 2004

Operational & Long-Term Observing Systems

- NWS WSR-88D
- NWS Rawinsonde
- GPS-Met IWV
- WRCC Surface Network

HMT-WEST 2010: Basin Scale Domain



HMT Observing Systems

- ESRL C-band Doppler Radar (SKYWATER)
- 915 MHz Profiler
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- S-band FMCW Profiler
- Impact (JW) Disdrometer
- Optical (Parsivel) Disdrometer
- Soil Moisture
- Sfc Met & TB Precip Gauge
- Hot Plate Precip Gauge
- ETI Precip Gauge
- Stream Level Logger
- Hi-Resolution Temperature Transects
- Snow Depth
- 3-D Multiple Doppler wind retrieval domain
- Range rings from SKYWATER

Operational and Long Term Observing Systems

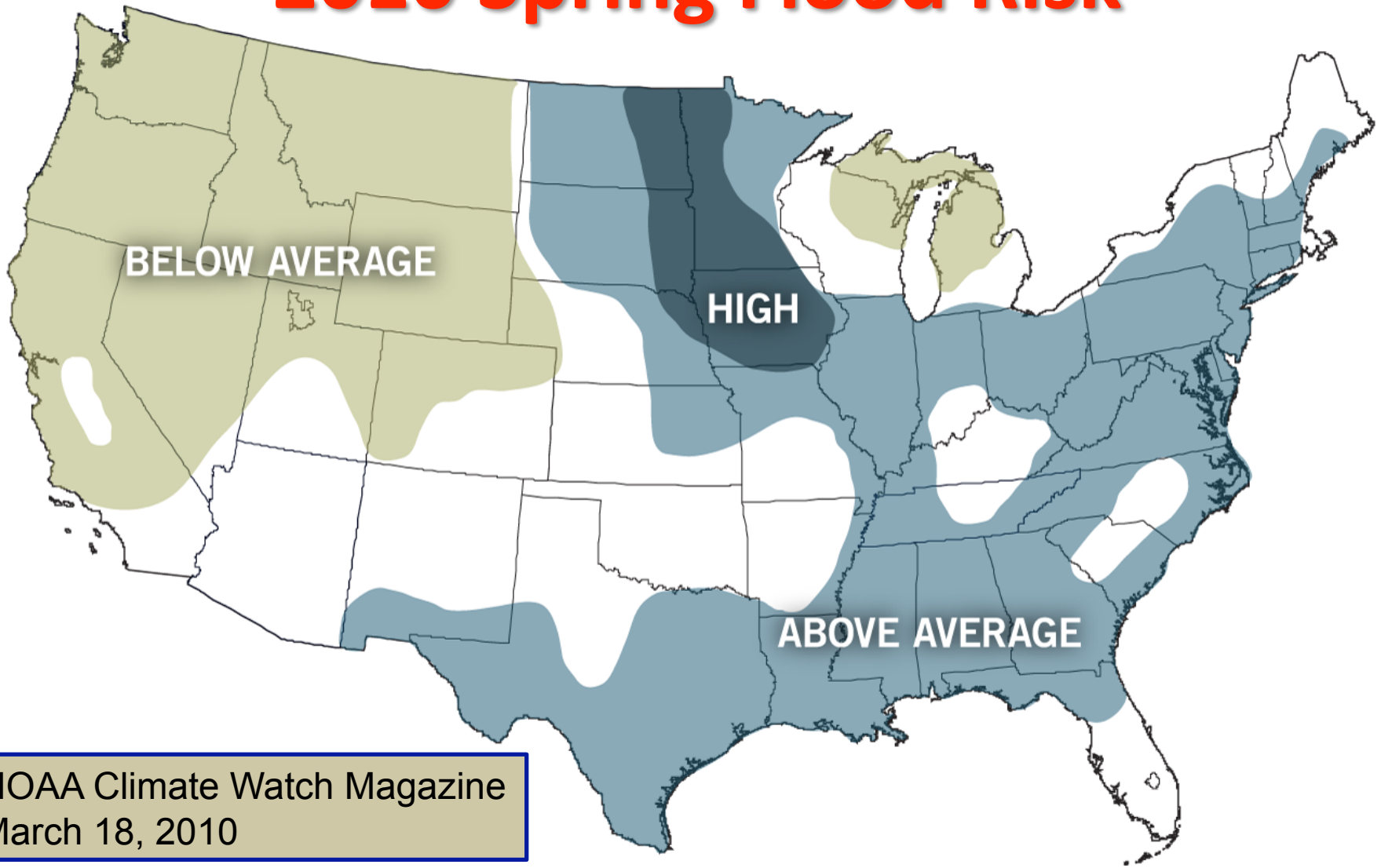
- NWS WSR-88D
- NWS Rawinsonde
- ALERT Precip. Gauge
- ALERT Snow Pillow
- SNOTEL Precip. Gauge and Snow Pillow
- RAWS Precip. Gauge
- WRCC Surface Network
- GPS-Met IWV

Water and a Changing Climate...

"Within the United States, extensive climate-related changes have been documented over the last century. These include increases in continental-average temperatures, rising sea levels in many coastal locations, an increased frequency of extreme heavy rainfall events, lengthening of the growing season, earlier snowmelt, and altered river flow volumes. Water is an issue in every region, but the nature of the potential impact varies. Drought is a serious problem in many regions, especially in the West and Southeast; and floods and water quality problems are likely to be amplified by climate change in most regions."

– Dr. Jane Lubchenco, NOAA Administrator

2010 Spring Flood Risk



NOAA Climate Watch Magazine
March 18, 2010

http://www.climatewatch.noaa.gov/2010/images/flood-risk-forecasted-for-one-third-of-u-s

Hydrometeorology Testbed (HMT) Program

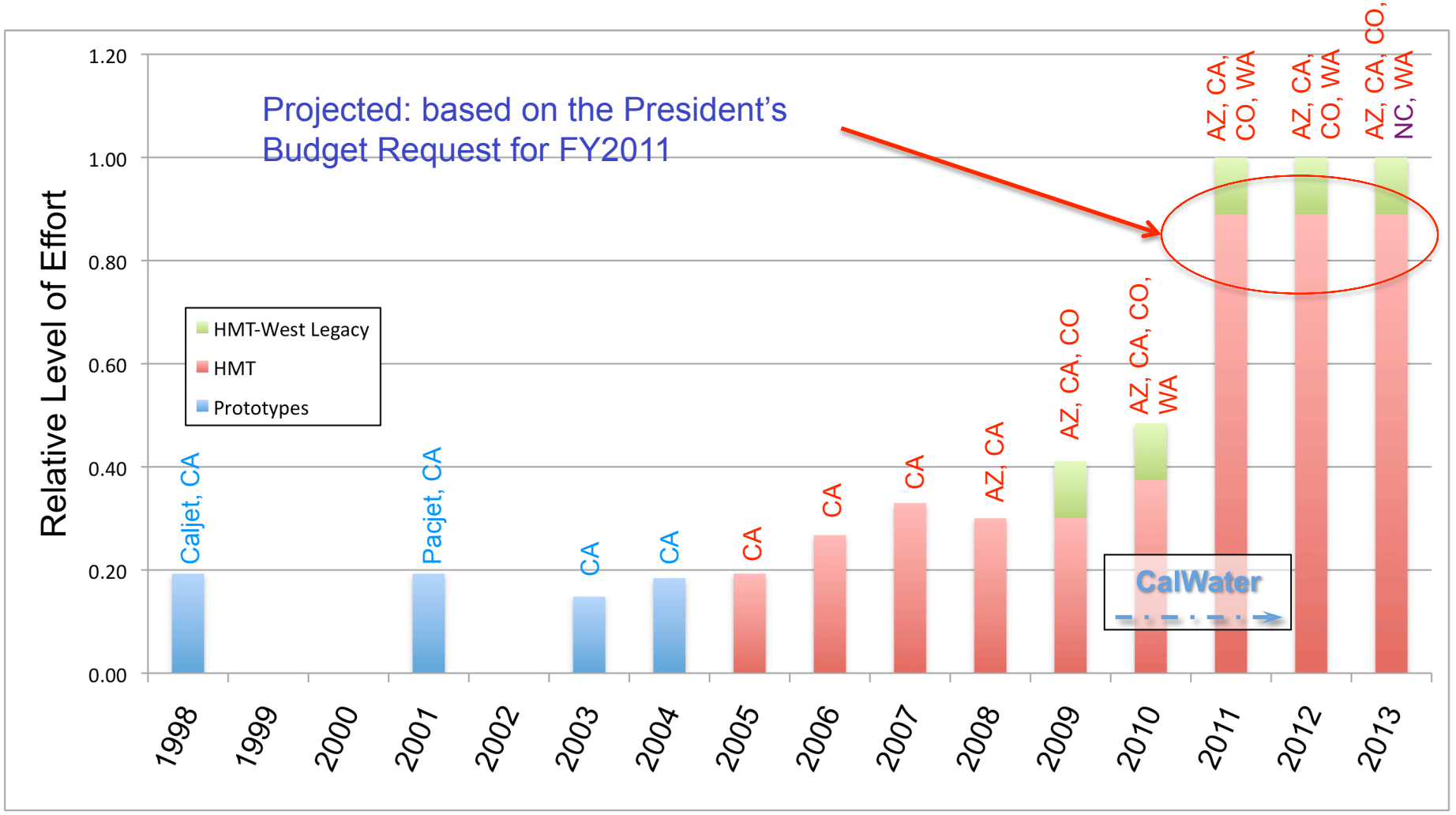
Developing New Tools to Help Meet the Nation's Water Resource Challenges in a Changing Climate

HMT

Implementation Plan for Science & Service

2009

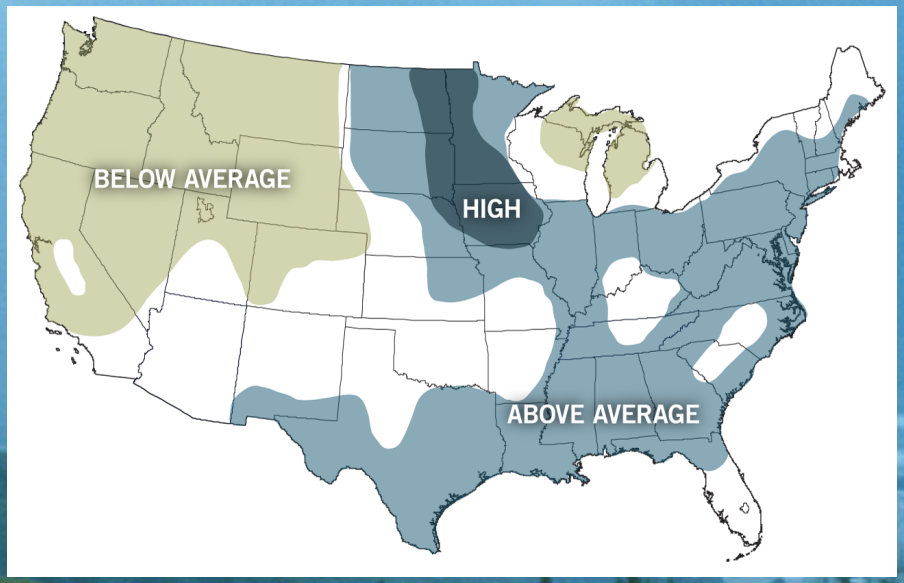
Timeline & Overall Effort



NOAA's Hydrometeorology Testbed (HMT)

"Tools for Water in a Changing Climate"

2nd Annual USWRP Testbed Workshop
May 4-5, 2010, Boulder, CO



Tim Schneider, HMT Project Manager
NOAA-ESRL, Boulder, CO

Other Talks…

Day 1, AM

- Developmental Testbed Center – *Bill Kuo (NCAR)*
- *Collaborative Science Technology & Applied Research – Sam Contorno (NWS)*
- The HMT-West Legacy Project: Current Status & Future Plans – *Allen White (NOAA)*
- *Ensemble Prediction System Development for HMT Application – Isidora Jankov (NOAA)*
- *Assessment of Extreme QPF & Development of Regional Extreme Event Thresholds Using Data from HMT-2006 & COOP Observers – Ellen Sukovich (ESRL)*
- *Statistics for HMT-West Ensemble Forecasts during the Winter 2009-2010 – Huiling Yuan*

Other Talks…

Day 1, PM

- CSTAR Activities at the University of Utah – *John Horel (University of Utah)*
- *Mechanisms for Predecessor Rain Events Ahead of Tropical Cyclones – Ben Moore (SUNY)*
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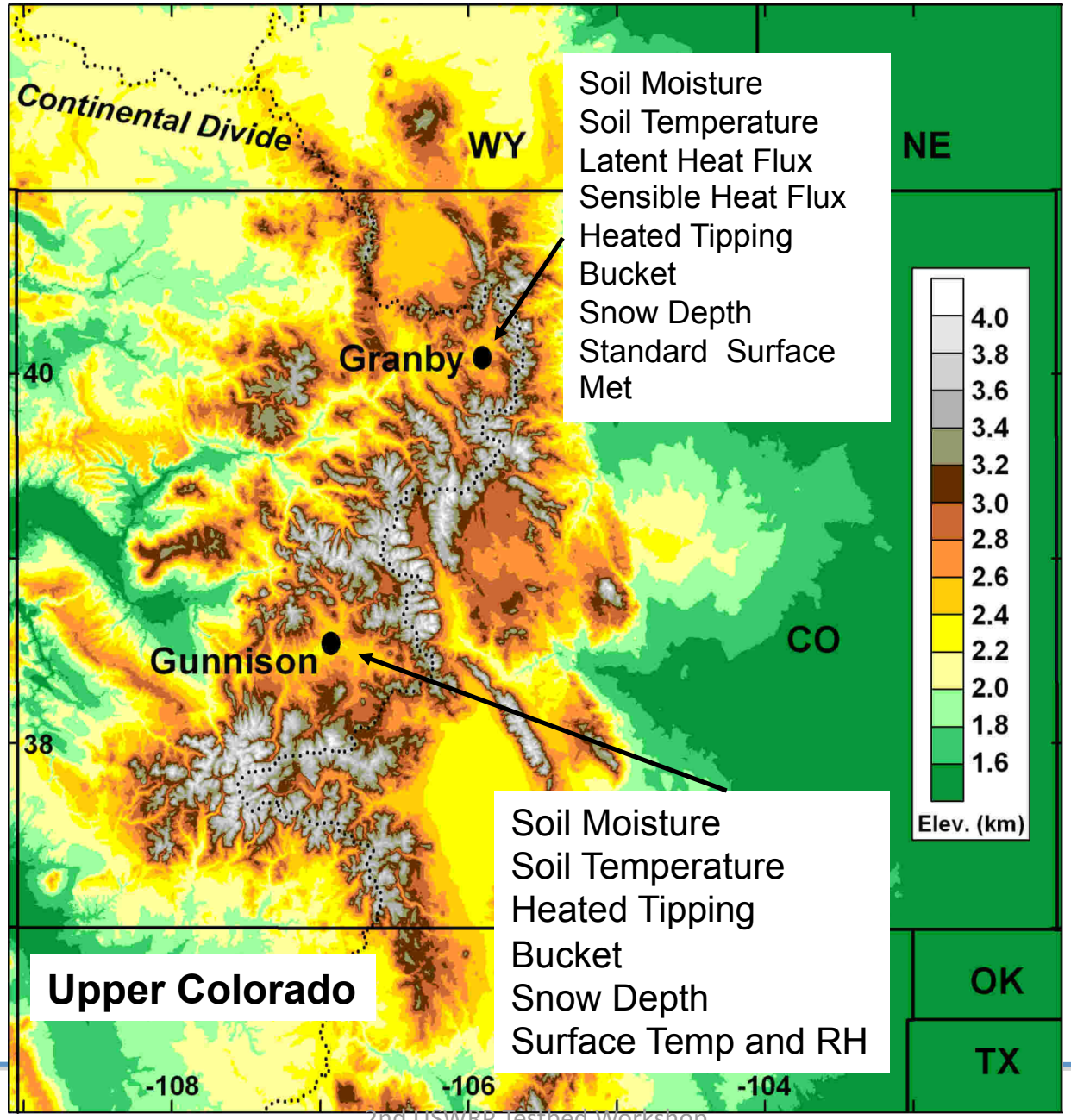
- *Development of Methodologies within a Testbed (per HMT) and their Subsequent Transition to a National System for Utilization by Operations – Ken Howard (NSSL)*

Other Talks…

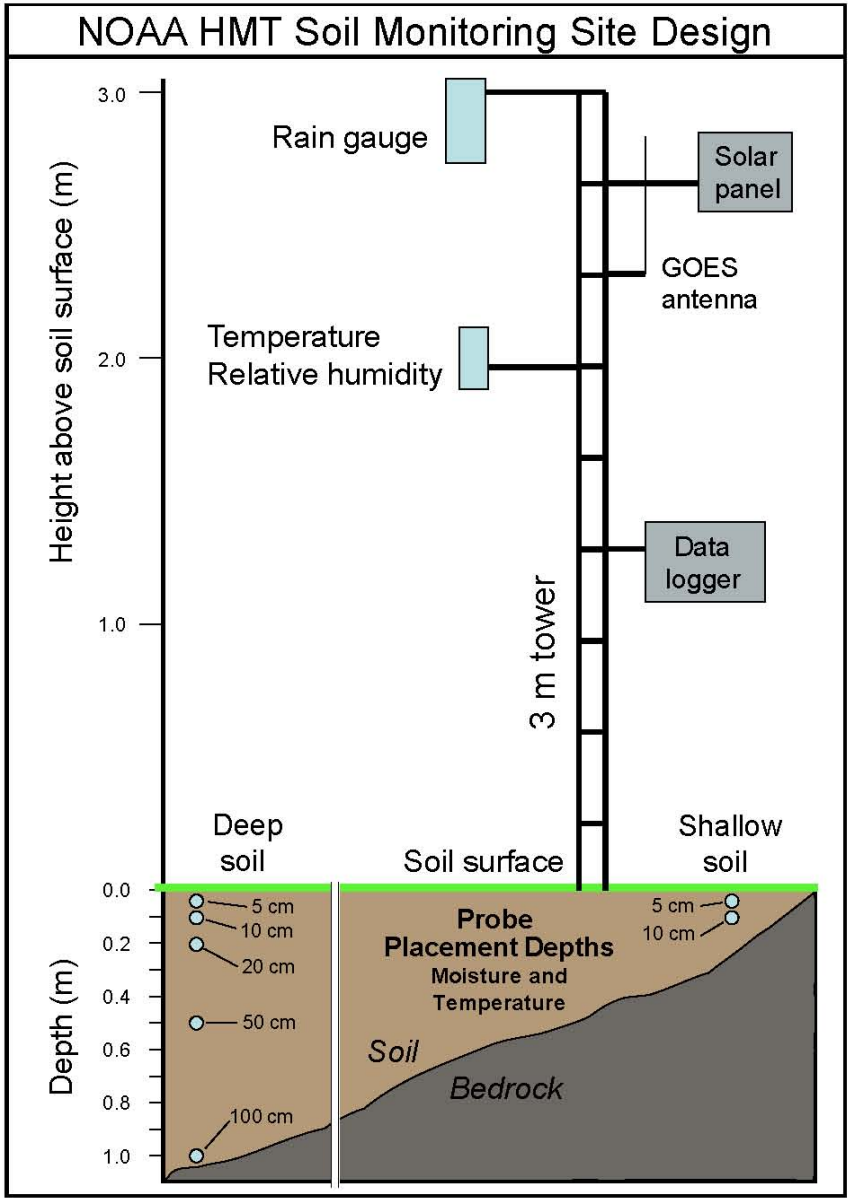
Day 2, PM

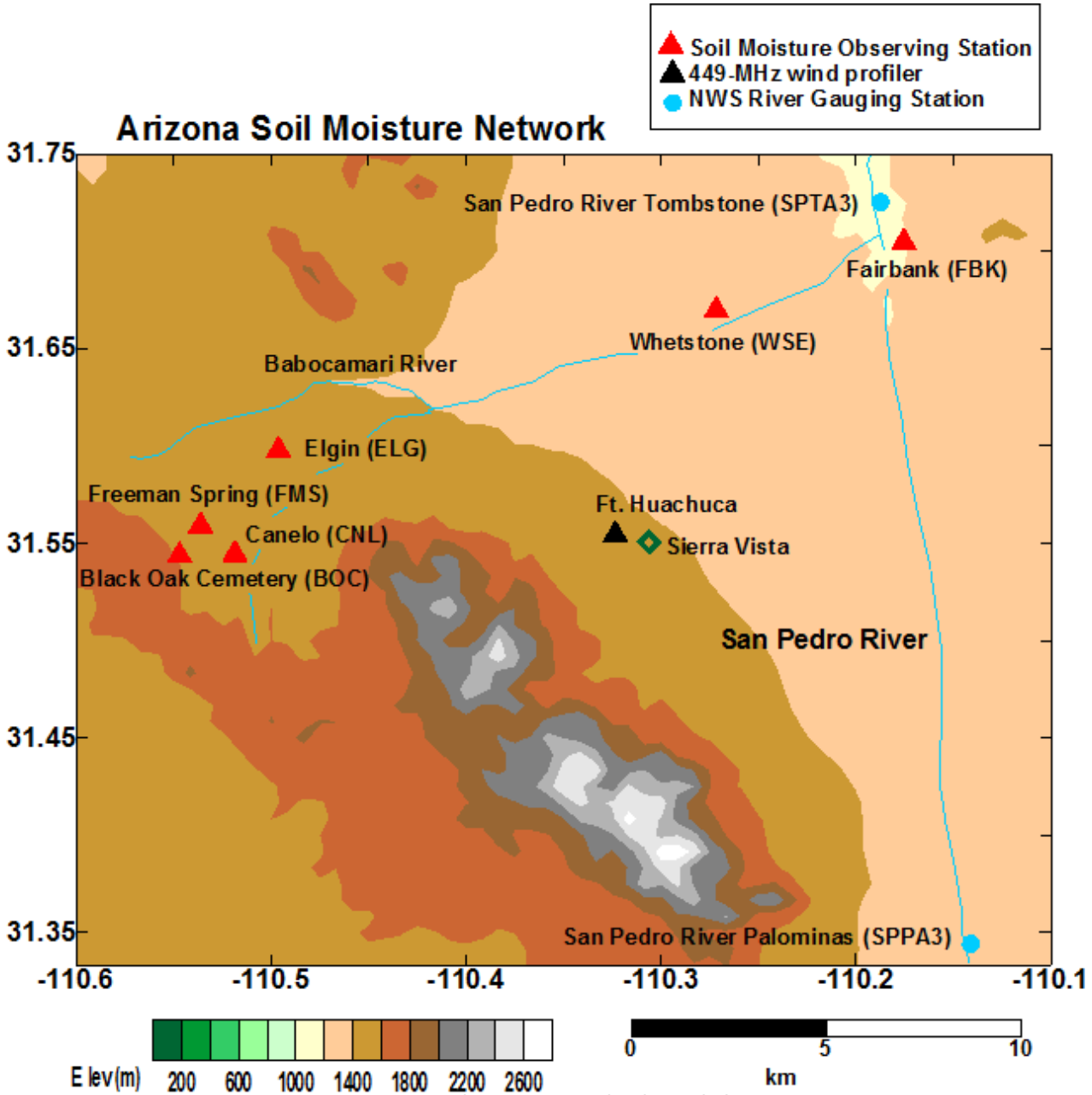
- HMT – NIDIS Collaboration – *(NIDIS – TBD)*
- THORPEX Overview & Connection to Testbeds – *Tom Hamill*

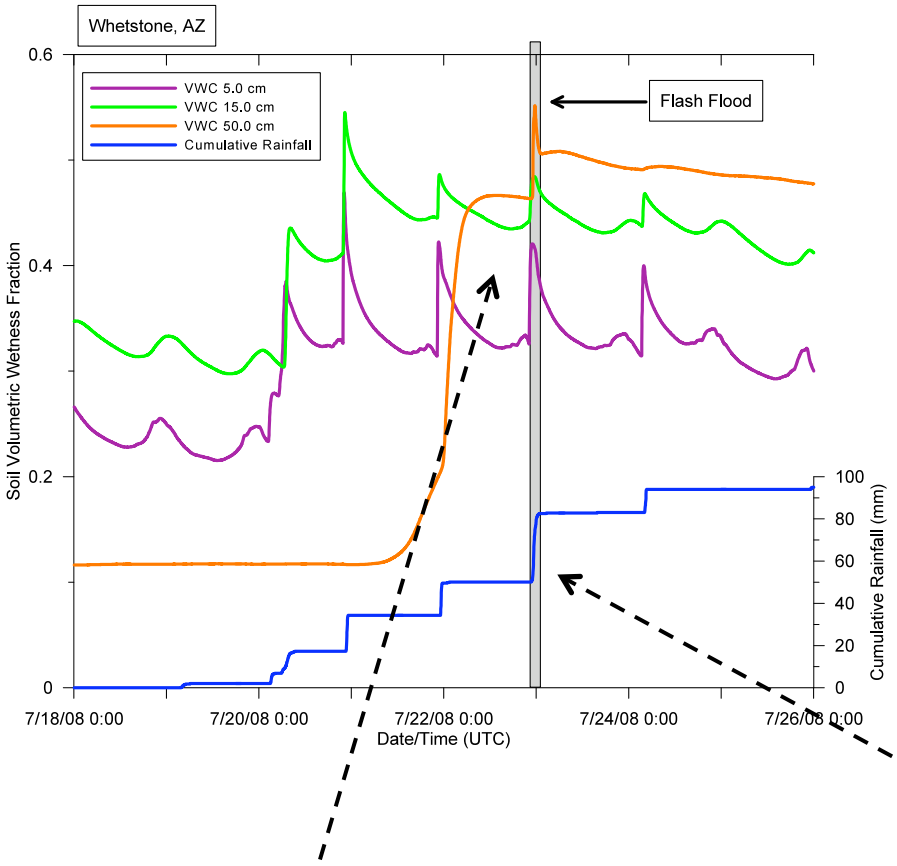
II. Example: Soil Moisture

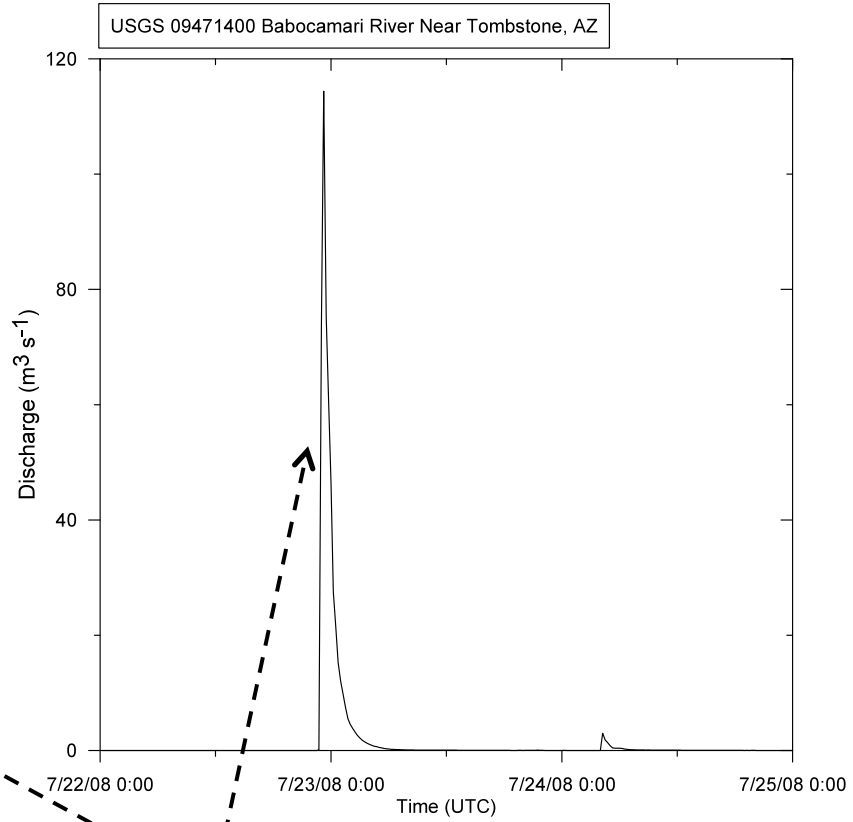

Continental Divide
WY
NE
Soil Moisture
Soil Temperature
Latent Heat Flux
Sensible Heat Flux
Heated Tipping Bucket
Snow Depth
Standard Surface Met
Granby
40
4.0
3.8
3.6
3.4
3.2
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
Elev. (km)
Gunnison
CO
38
Soil Moisture
Soil Temperature
Heated Tipping Bucket
Snow Depth
Surface Temp and RH
Upper Colorado
OK
TX
-108
-106
-104

Granby, Colorado



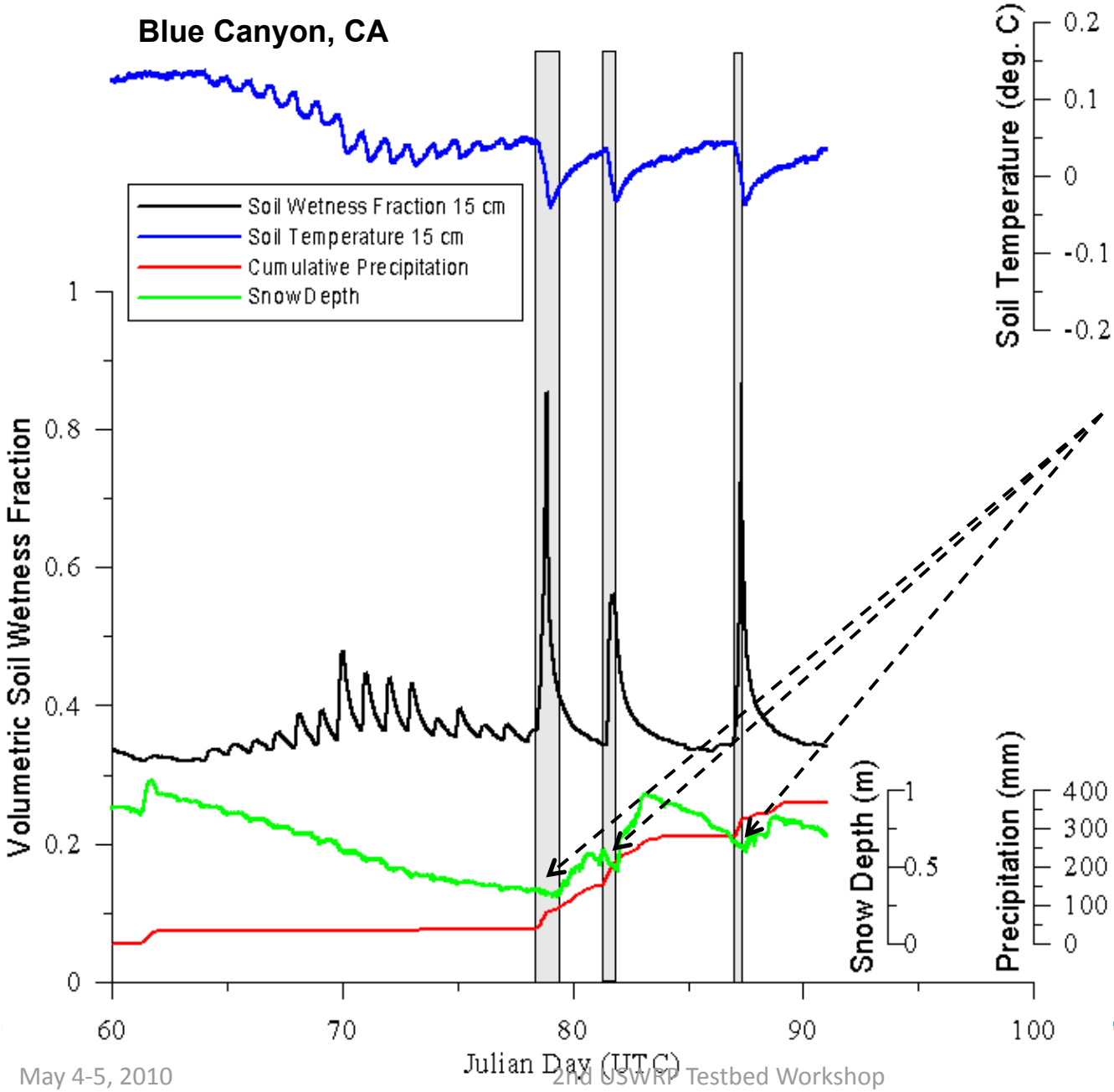

Soil Moisture Observing Station
449-MHz wind profiler
NWS River Gauging Station
Arizona Soil Moisture Network
31.75
31.65
31.55
31.45
31.35
-110.6
-110.5
-110.4
-110.3
-110.2
-110.1
San Pedro River Tombstone (SPTA3)
Fairbank (FBK)
Whetstone (WSE)
Babocamari River
Elgin (ELG)
Freeman Spring (FMS)
Canelo (CNL)
Black Oak Cemetery (BOC)
Ft. Huachuca
Sierra Vista
San Pedro River
San Pedro River Palominas (SPPA3)
Elev(m)
200
600
1000
1400
1800
2200
2600
0
5
10
km





The monsoon rain event occurring on 00 UTC 22July finally brought the soil column to saturation.

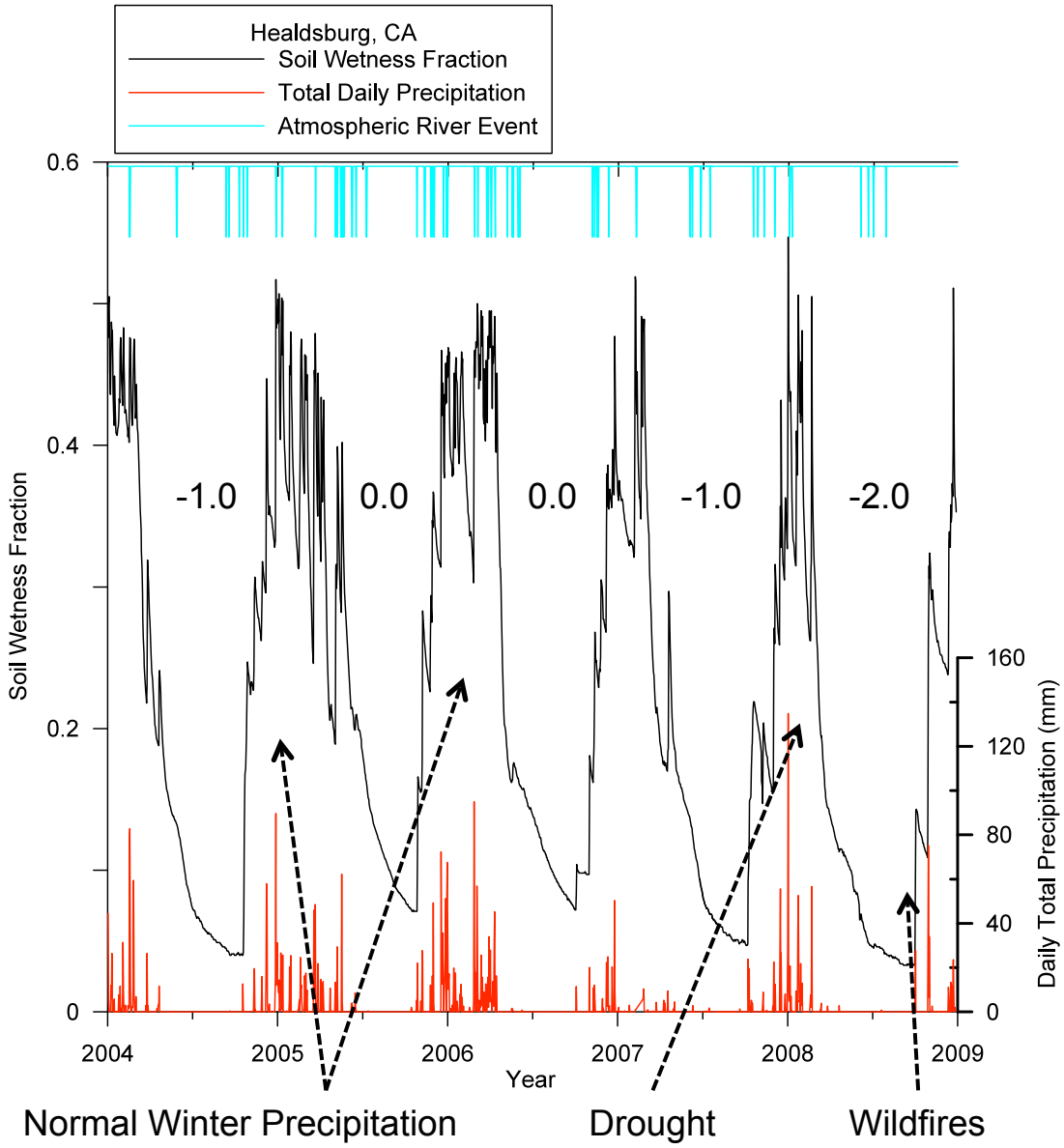
Flooding coincided with a storm that dropped 30 mm of precipitation on top of saturated soil near 00 UTC 23 July.



Snowpack is decreasing at the same time precipitation is being observed suggesting that rain is falling on the snowpack.

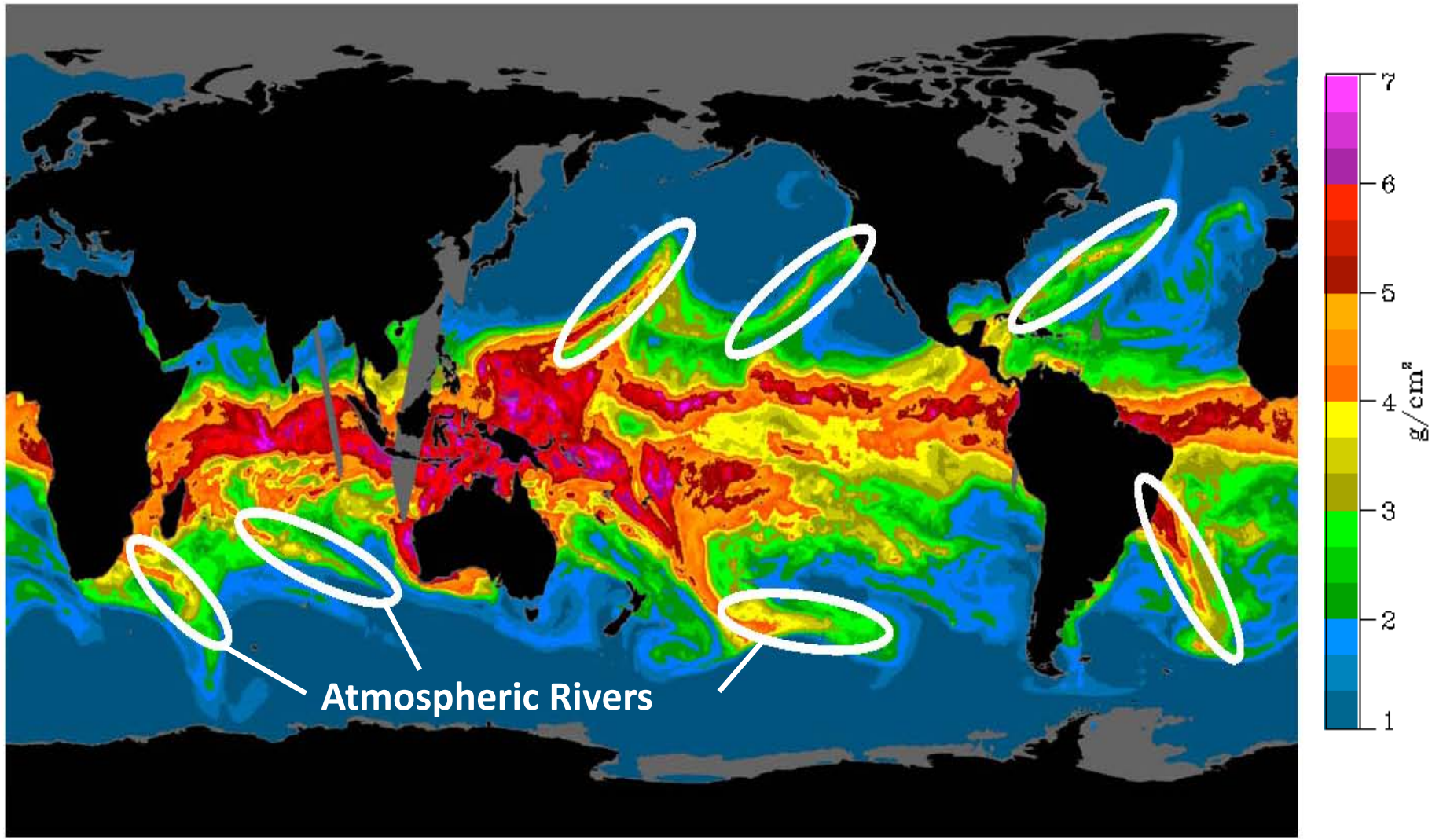
Rain is quickly moving through the snowpack and saturating the ground under the snowpack.

Soil wetness fractions exceeding 0.4 suggest that ponds of water are forming under the snowpack in the saturated soil.


Healdsburg, CA
Soil Wetness Fraction
Total Daily Precipitation
Atmospheric River Event
0.6
0.4
0.2
0
Soil Wetness Fraction
-1.0
0.0
0.0
-1.0
-2.0
160
120
80
40
0
Daily Total Precipitation (mm)
2004
2005
2006
2007
2008
2009
Year
Normal Winter Precipitation
Drought
Wildfires

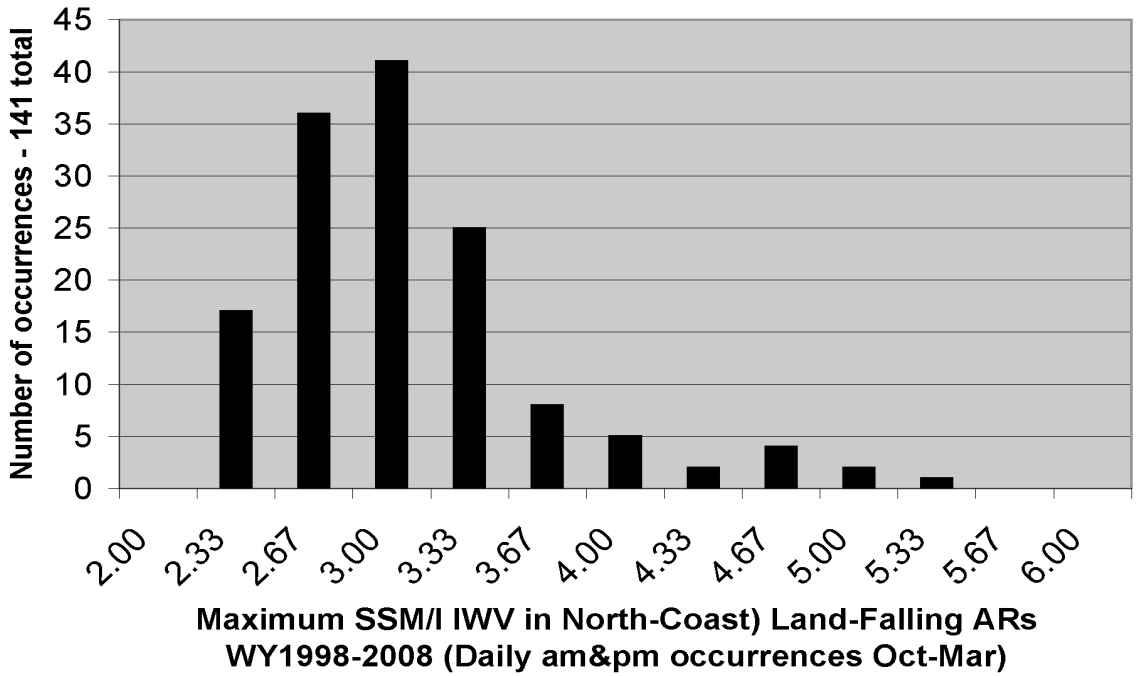
III. Example: Atmospheric Rivers

SSM/I Display of Integrated Water Vapor from February 16, 2004

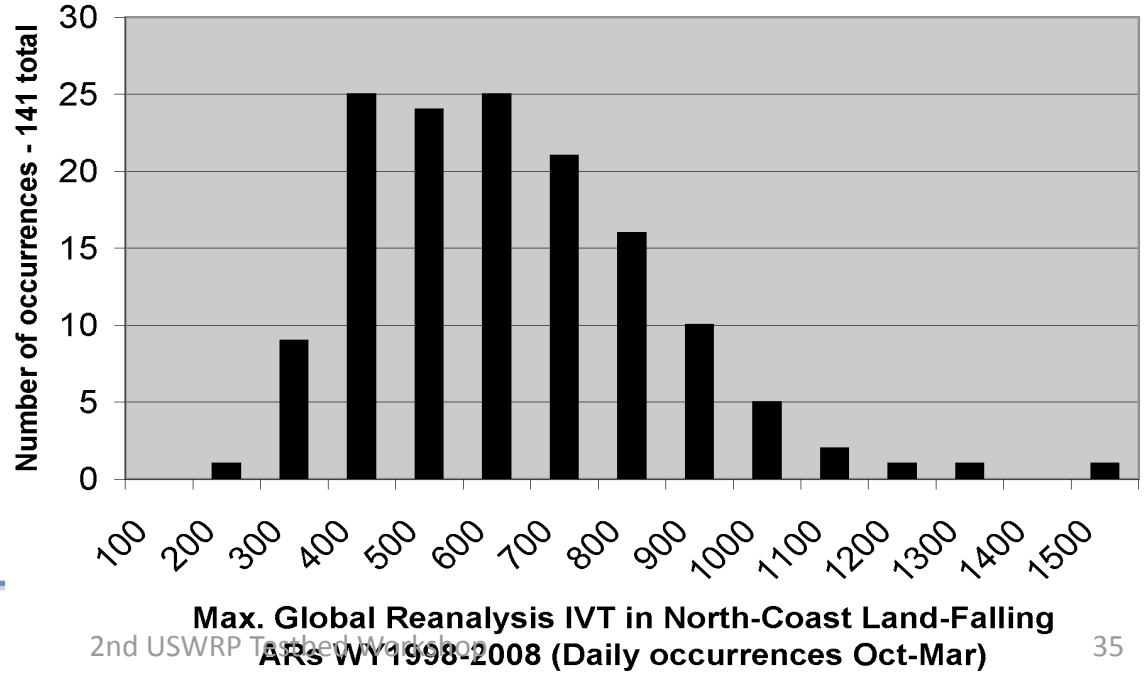


North Coast:
(41.0° - 52.5°N)
Oct-Mar

10 contiguous pixels (~5000 km^2) of the most moist SSM/I IWV in each AR w/in 1000 km of coast

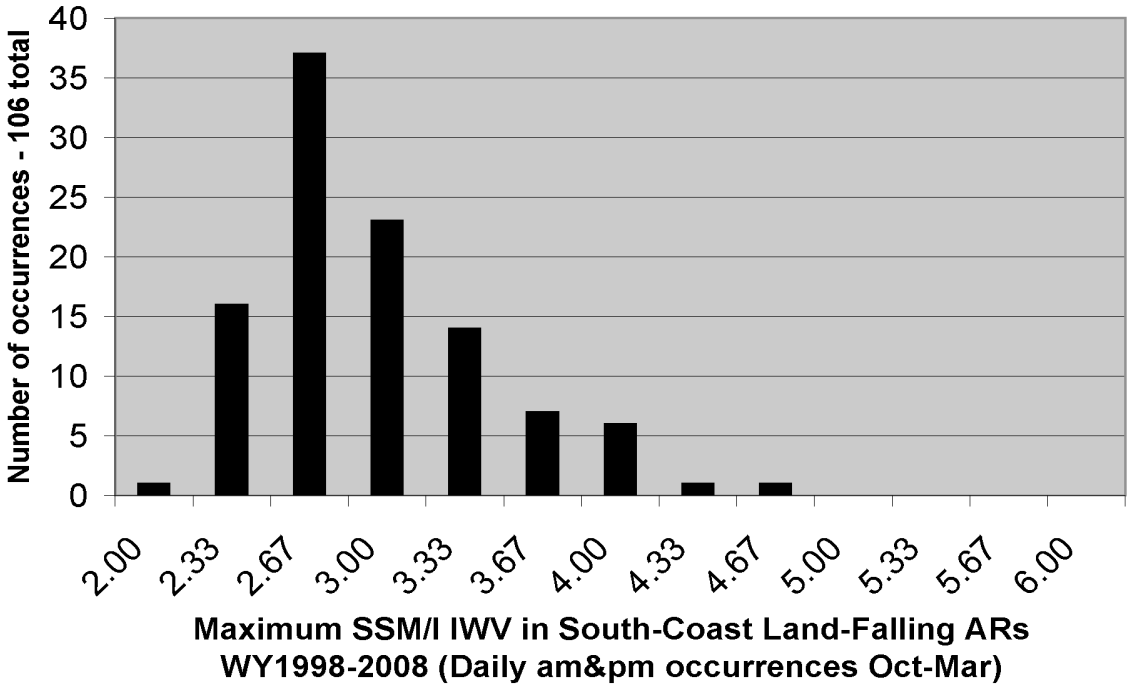


From the above inventory, the strongest vertically integrated vapor flux in each AR w/in 1000 km of coast

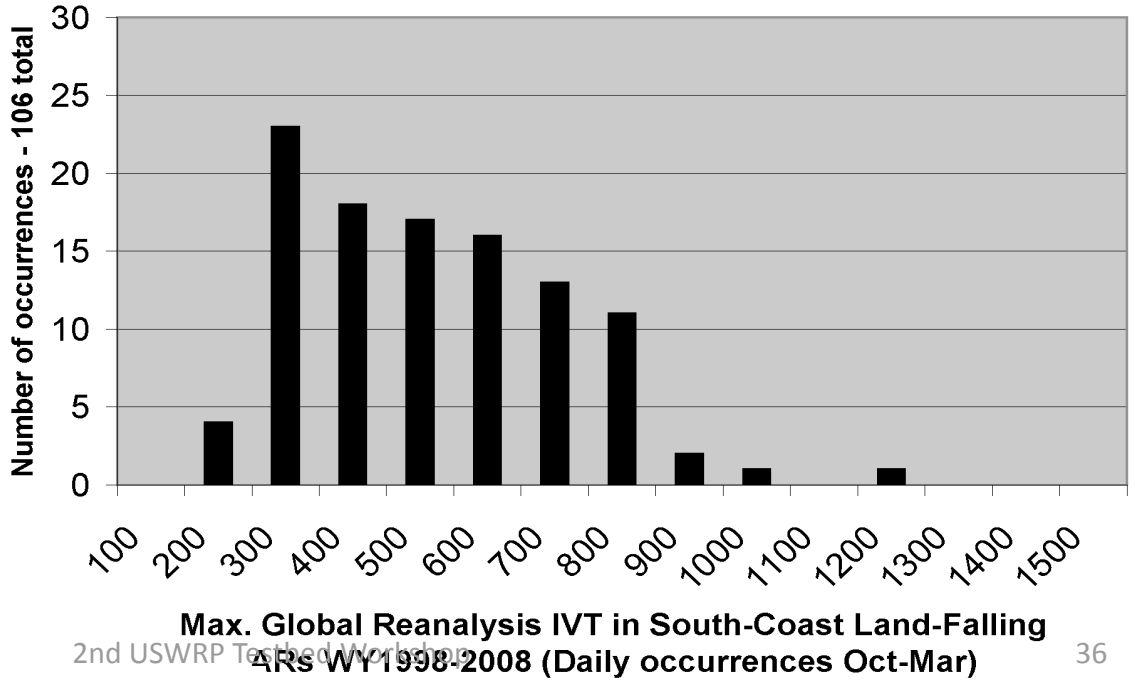


South Coast:
(32.5° - 41.0°N)
Oct-Mar

10 contiguous pixels (~5000 km^2) of the most moist SSM/I IWV in each AR w/in 1000 km of coast

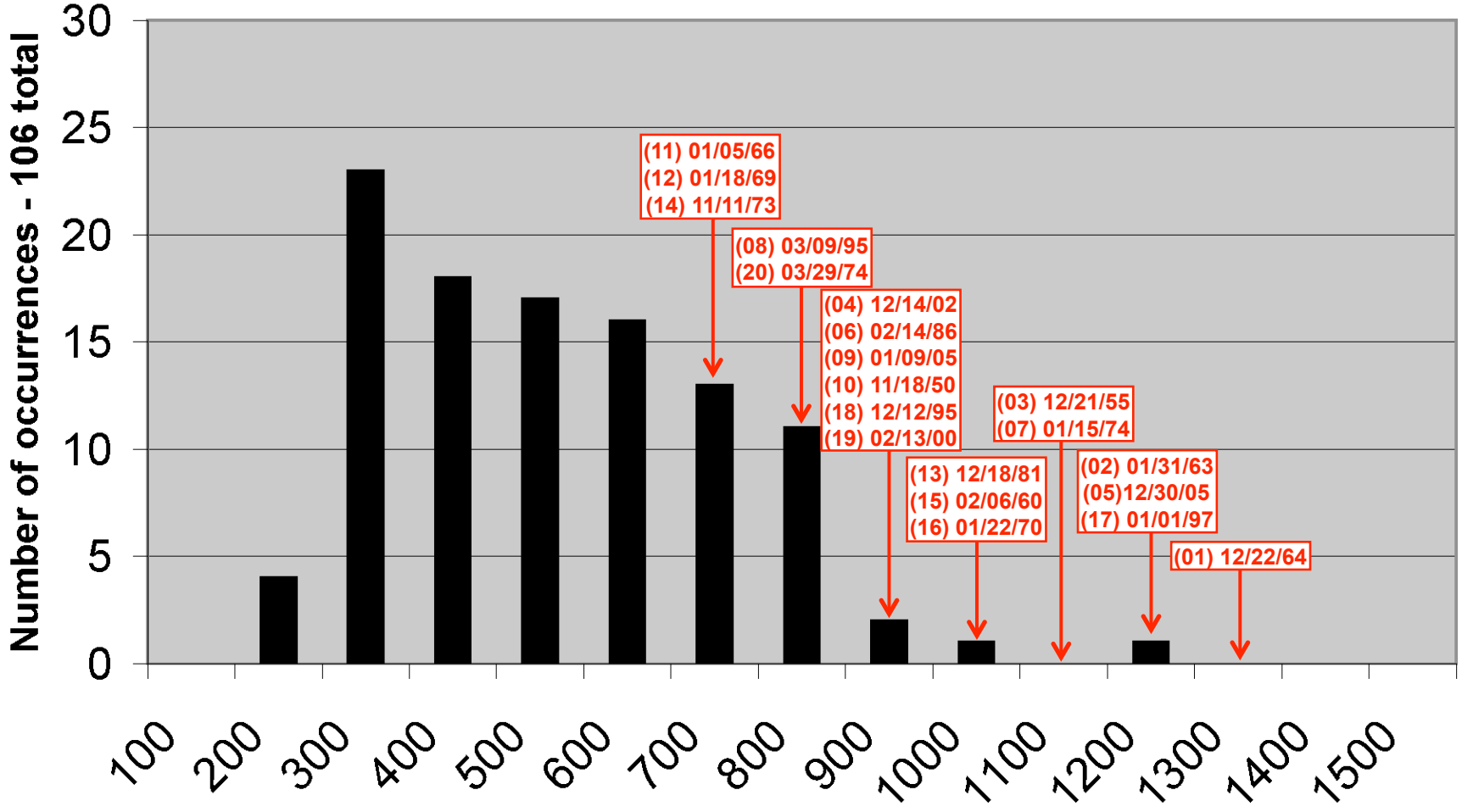


From the above inventory, the strongest vertically integrated vapor flux in each AR w/in 1000 km of coast



CA 20 heaviest 3-day precip. events:

From the above inventory, a histogram of the strongest vertically integrated vapor flux in each AR w/in 1000 km of coast. Dates from the 20 top 3-day precip. events between 1949-2007 (from the CDC 0.25x0.25 deg unified precip. dataset) in the Sierra from Wes Junker are also marked (http://www.hpc.ncep.noaa.gov/research/California_major_rains.htm).

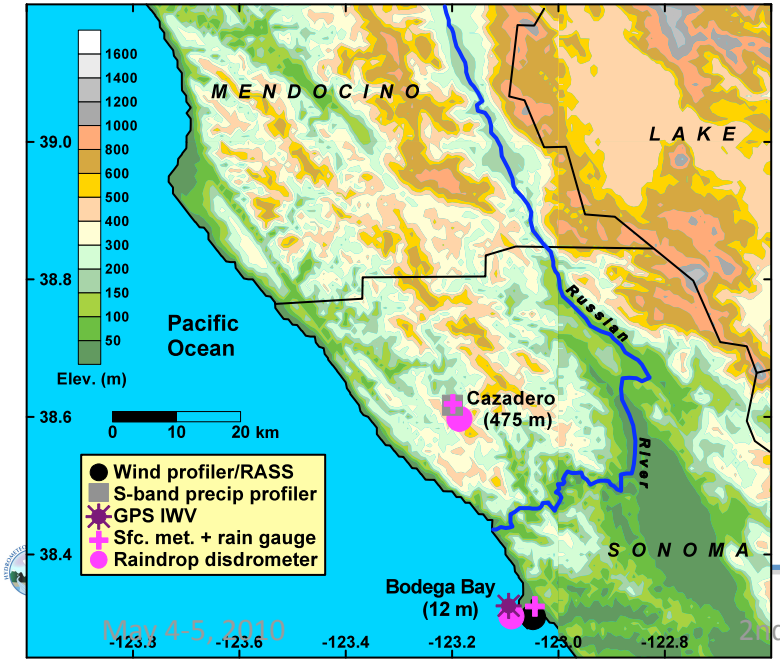


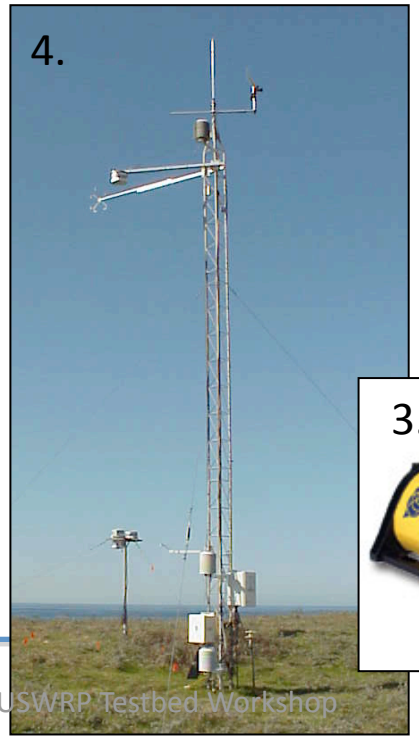
Atmospheric River Observatory (ARO): Russian River Prototype

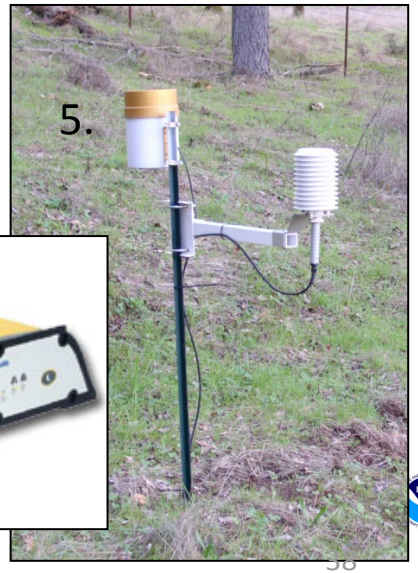
Objectives: monitor key atmospheric river and precipitation characteristics

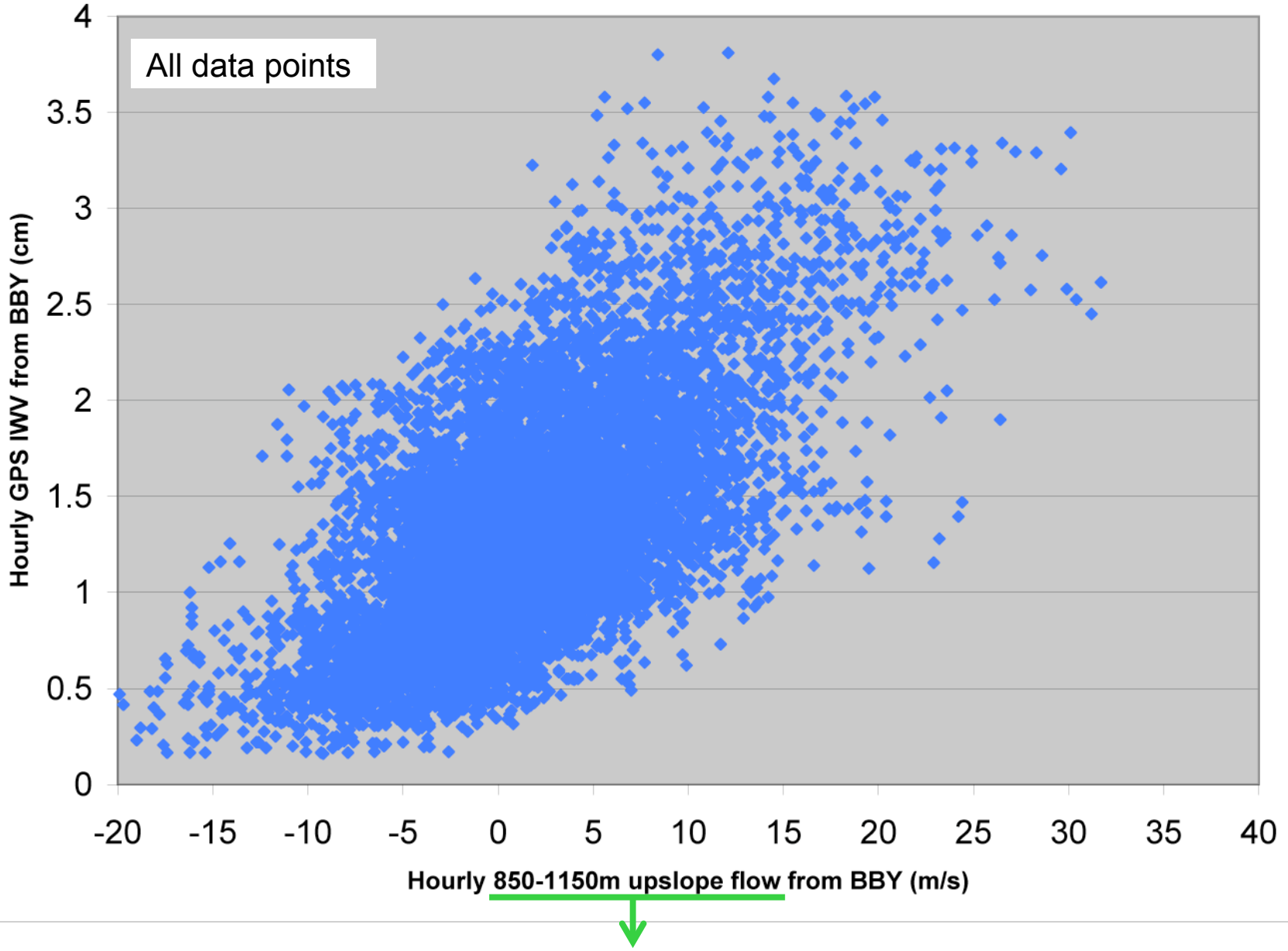
Observing systems:

1. Wind profiler/RASS
2. S-band radar
3. GPS-IWV
4. Surface met
5. Rain gauges
6. Disdrometer

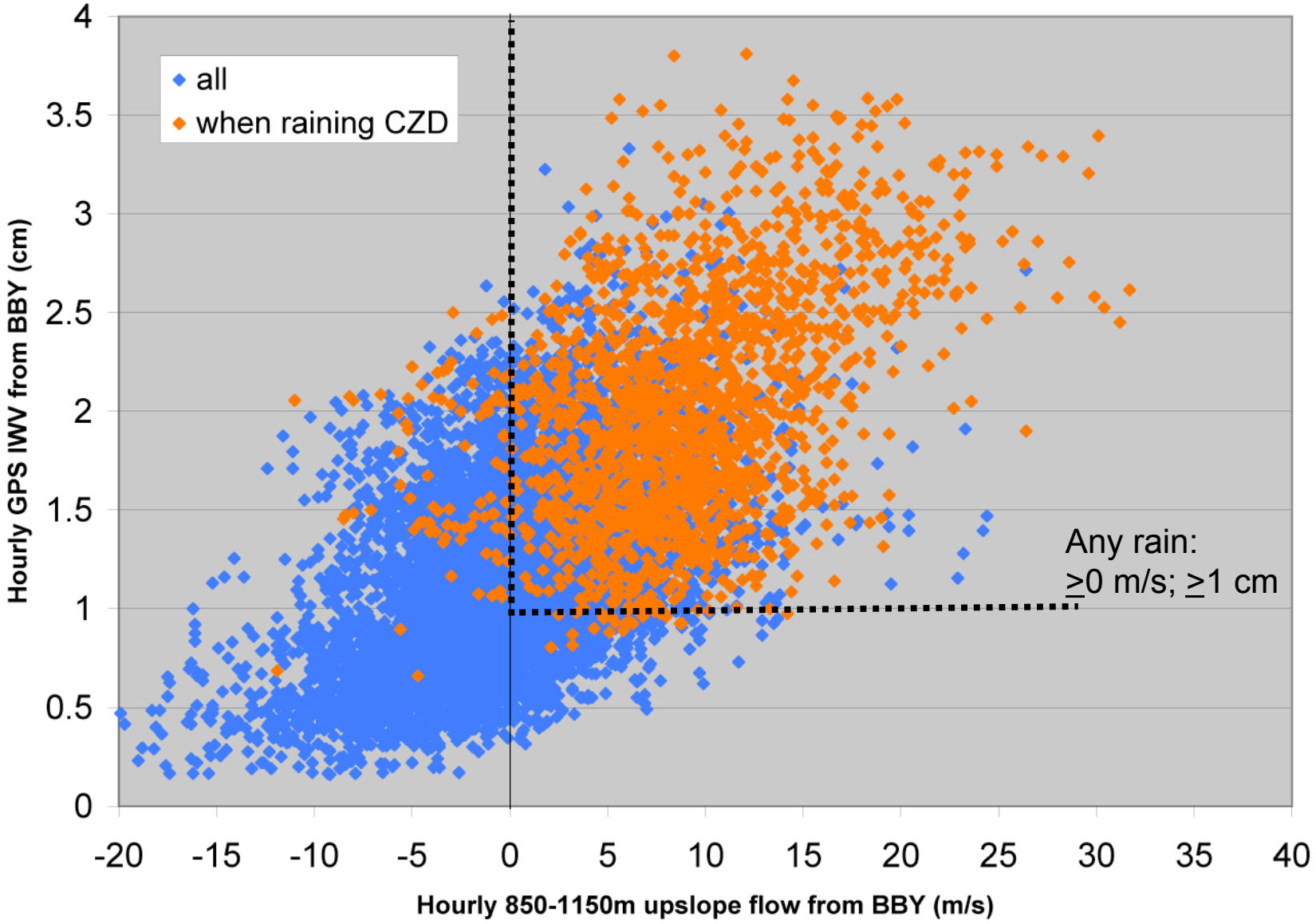


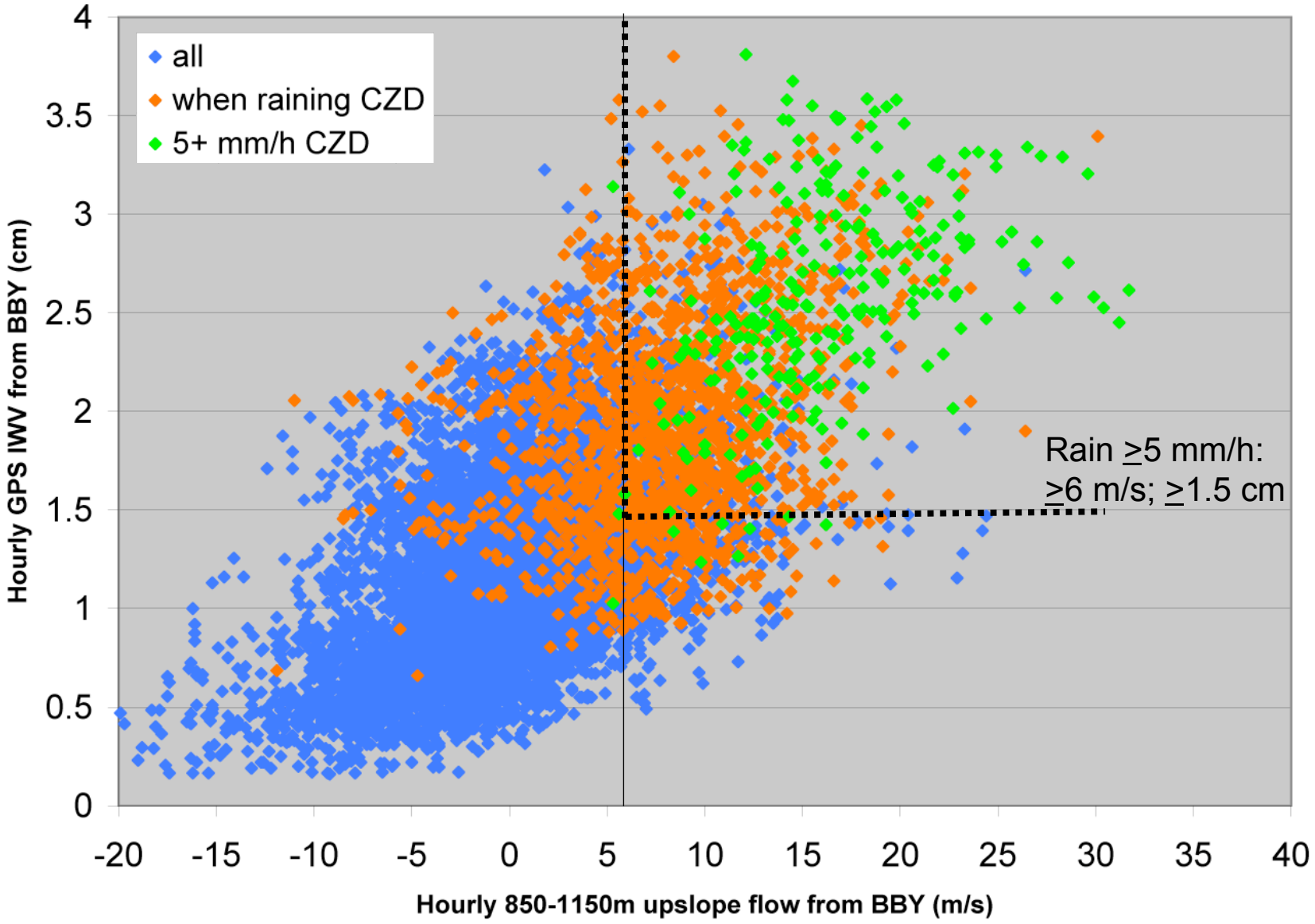


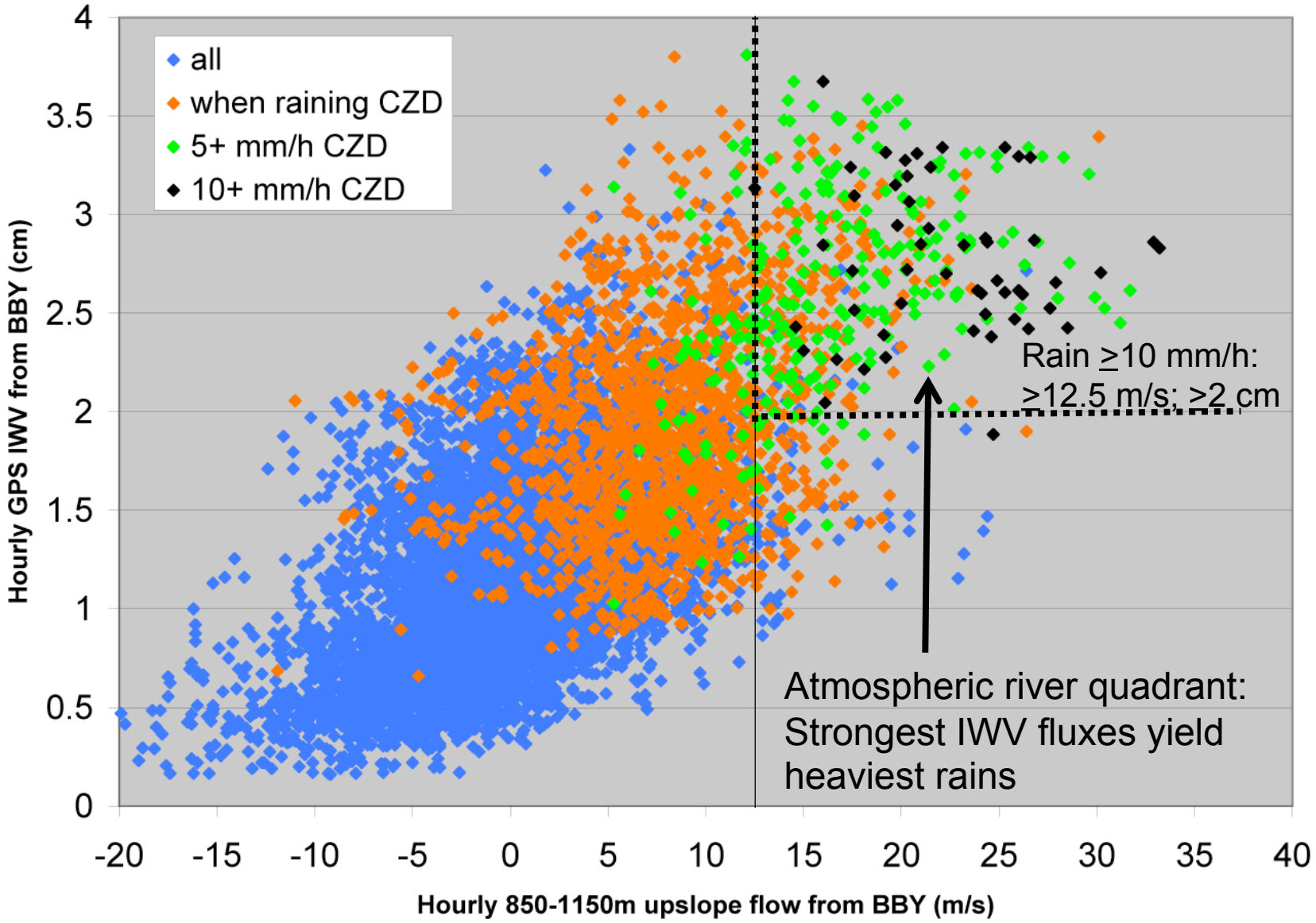




Component of the flow in the orographic controlling layer directed along 230°, i.e., orthogonal to the axis of the coastal mtns

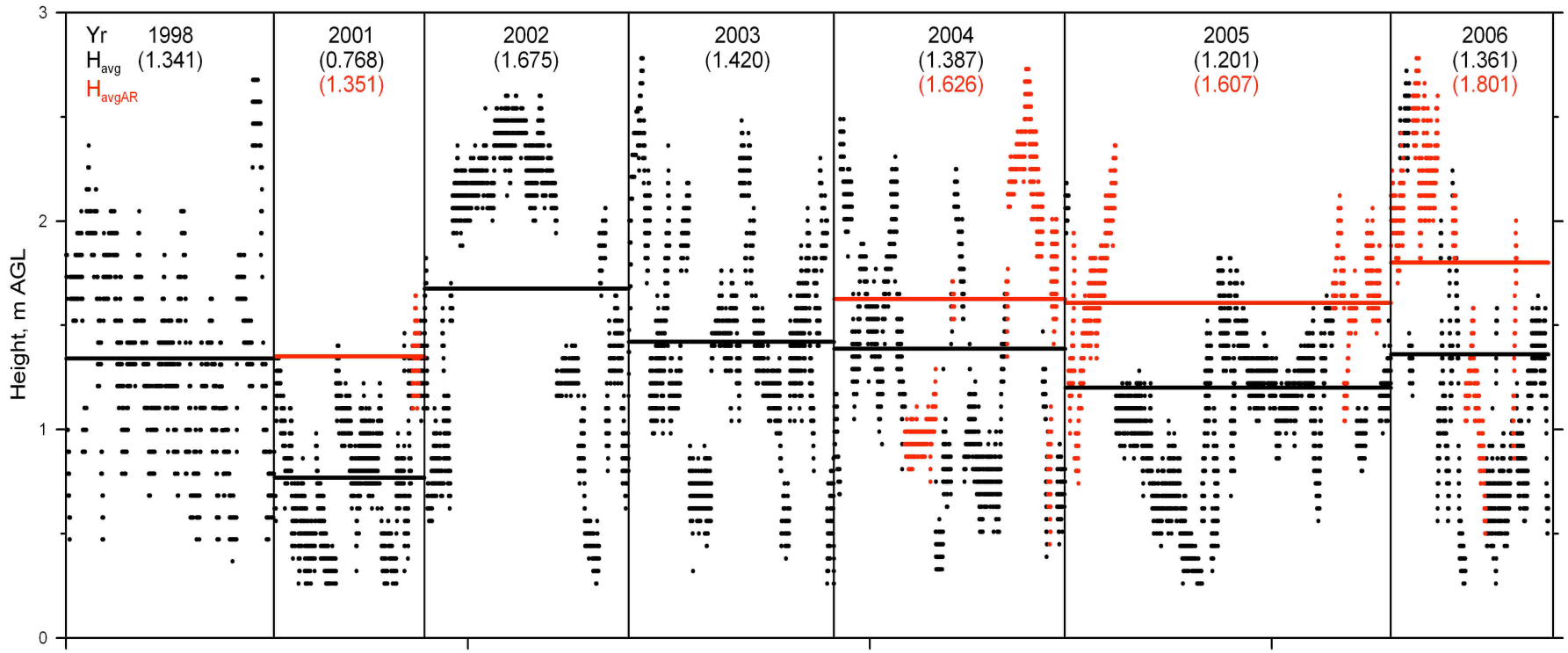

all
when raining CZD
Any rain:
≥0 m/s; ≥1 cm
Hourly GPS IWV from BBY (cm)
Hourly 850-1150m upslope flow from BBY (m/s)
4
3.5
3
2.5
2
1.5
1
0.5
0
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40


all
when raining CZD
5+ mm/h CZD
Rain ≥5 mm/h:
≥6 m/s; ≥1.5 cm
Hourly GPS IWV from BBY (cm)
Hourly 850-1150m upslope flow from BBY (m/s)
4
3.5
3
2.5
2
1.5
1
0.5
0
-20
-15
-10
-5
0
5
10
15
20
25
30
35
40

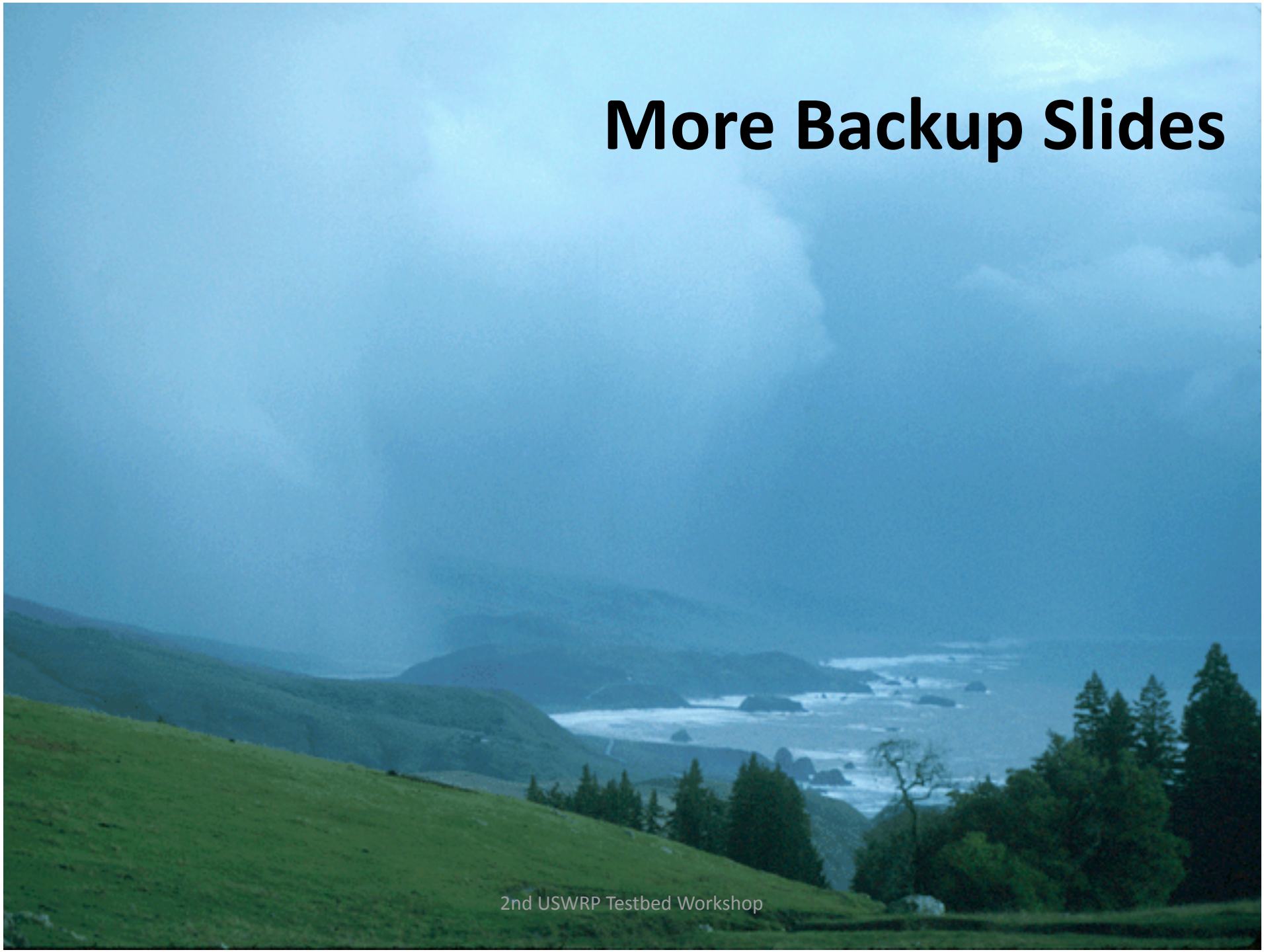

all
when raining CZD
5+ mm/h CZD
10+ mm/h CZD
Hourly GPS IWV from BBY (cm)
Hourly 850-1150m upslope flow from BBY (m/s)
Rain ≥10 mm/h:
≥12.5 m/s; ≥2 cm
Atmospheric river quadrant:
Strongest IWV fluxes yield
heaviest rains

Snow levels measured by the S-band radar at CZD during the 4 winters averaged 421 m (1380 ft) higher in AR conditions:

Warm conditions & more rain = increased flooding

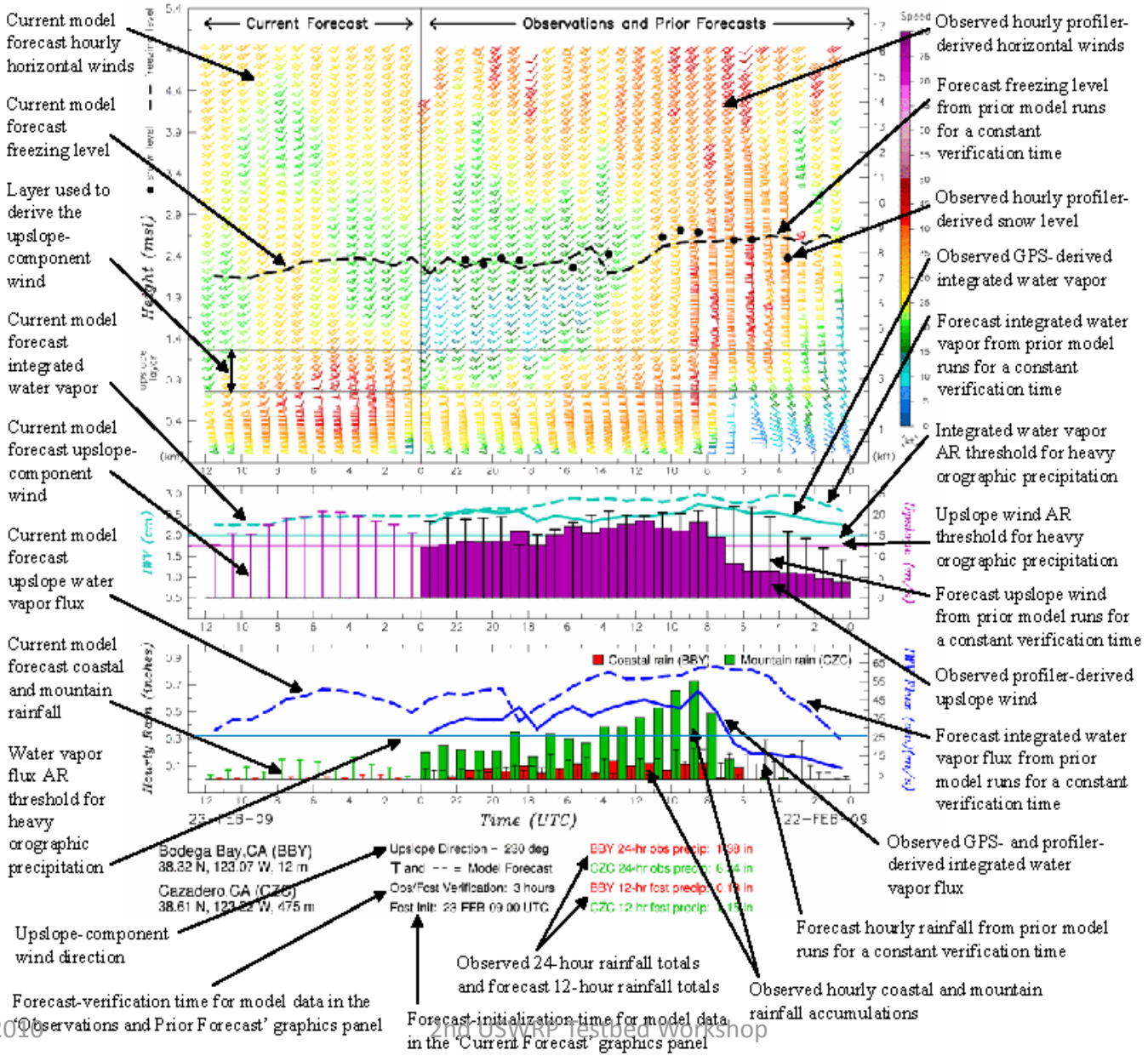


More Backup Slides

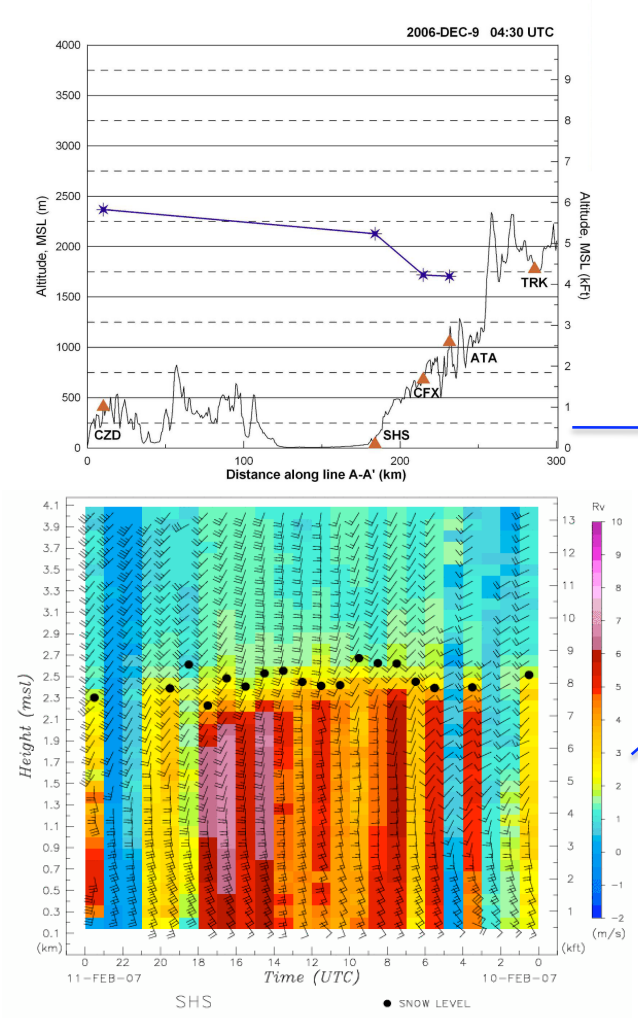


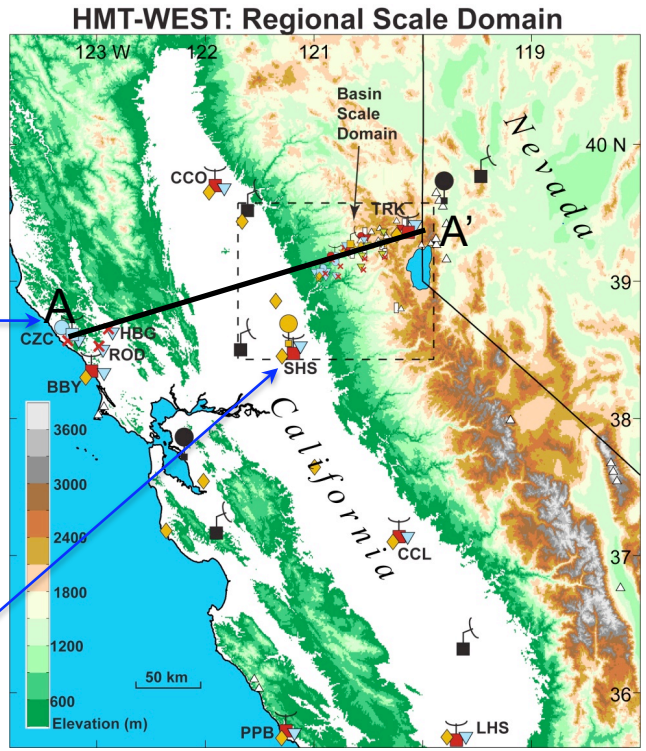
Coastal Atmospheric River (AR) Monitoring and Early Warning System

Profiler and precipitation observations provided by the NOAA/ESRL Physical Sciences Division
GPS observations and model forecast provided by the NOAA/ESRL Global Systems Division



Snow Level Varies Significantly in Space & Time





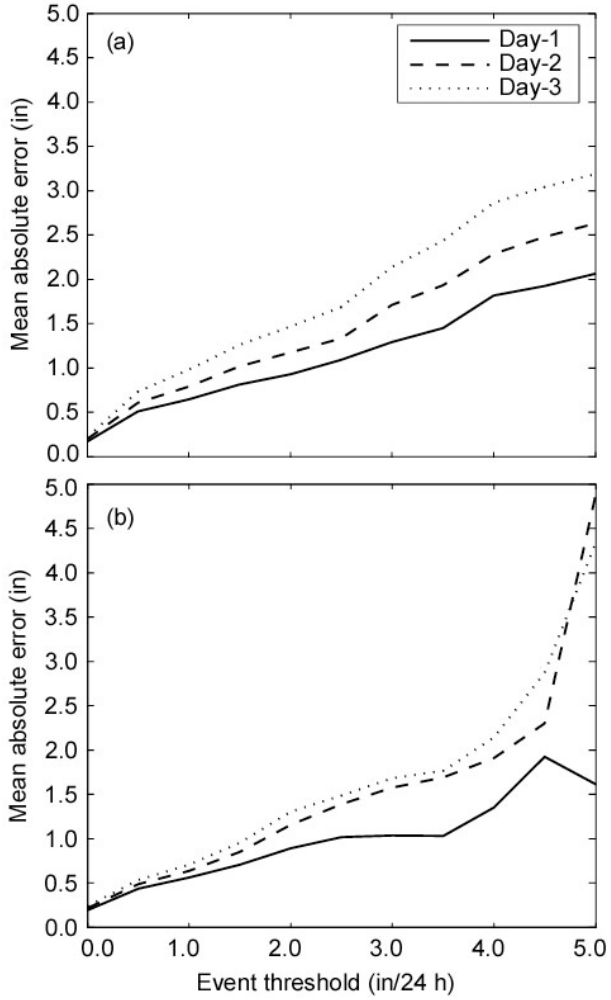


Figure 6. Mean absolute error for 24-h precipitation thresholds (in inches) by forecast lead time (Day-1, Day-2, and Day-3) for the (a) CNRFC and (b) NWRFC.

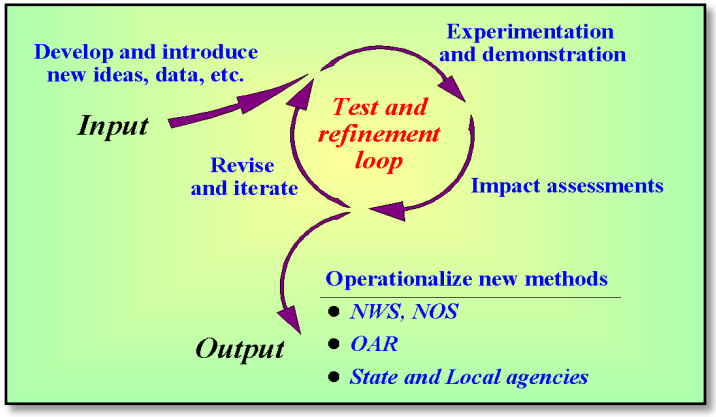
Partnerships on Research, Demonstration, Evaluation & Impact Assessment

NOAA Research:
- ESRL – PSD
- ESRL – GSD
- NSSL

National Weather Service:
- OHD
- NCEP/HPC
- OCWWS/NOHRSC
- Western Region HQ
- Eastern Region HQ
- Southern Region HQ
- River Forecast Centers: California-Nevada; Colorado Basin; Southeast
- Weather Forecast Offices: Eureka, Monterey, Sacramento, Reno, Seattle, Raleigh-Durham

NESDIS
- STAR

- Federal Agencies
  - NASA; USGS; US-ACE
- State Agencies
  - CA-DWR; NC-RENCI
- Local Agencies
  - SAFCA
- Academic
  - CU; CSU; UW; UCSD/Scripps; NCAR; Western Regional Climate Center



HMT Observing Systems

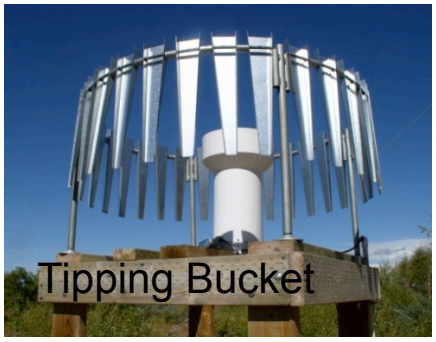
Scanning Radars

Profiling Radars

GPS IWV & Sounding Systems

HMT Observing Systems

Precipitation Gauges



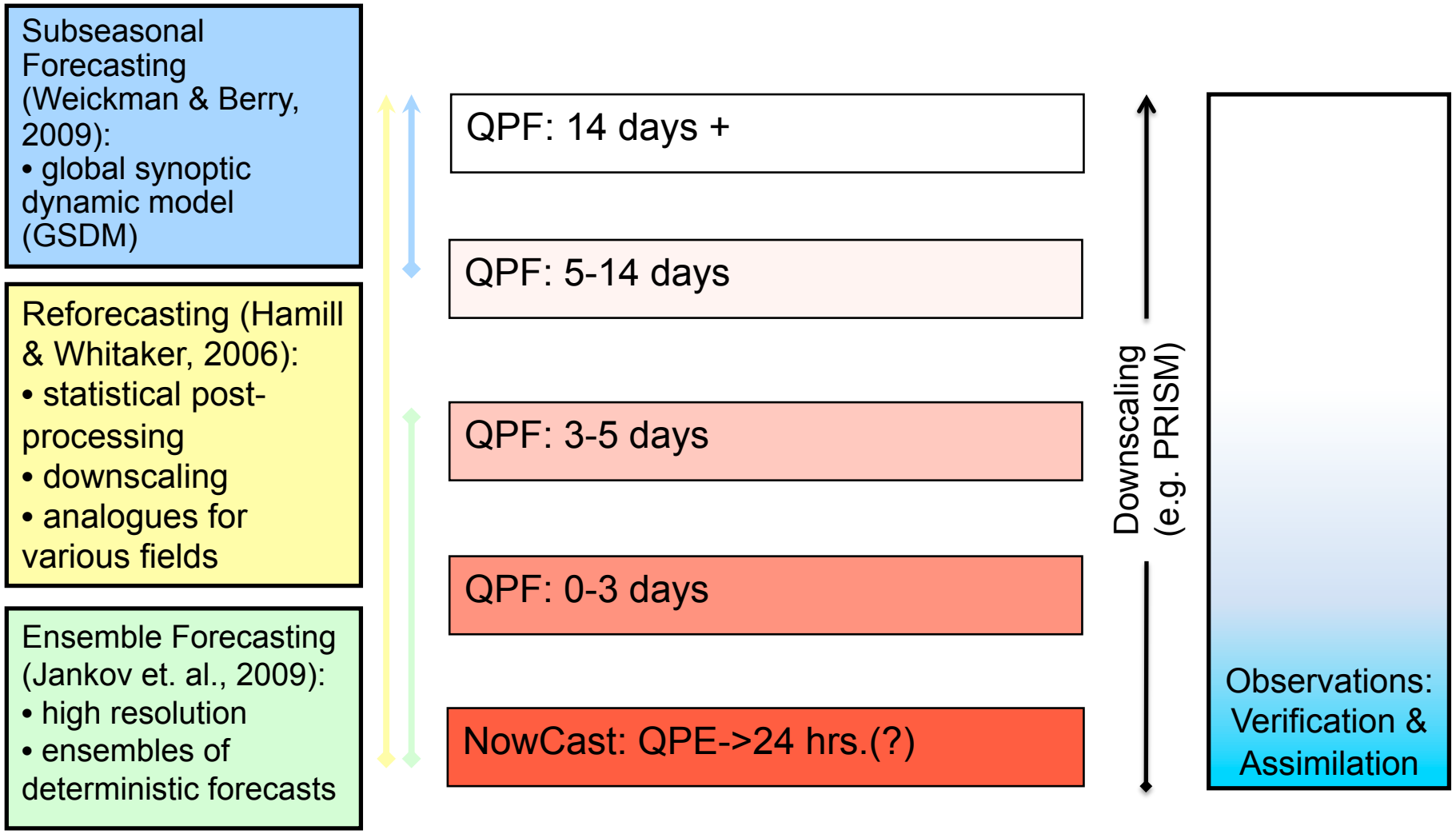
Precipitation Disdrometers

Surface Meteorology
& Snow Depth

Soil Moisture

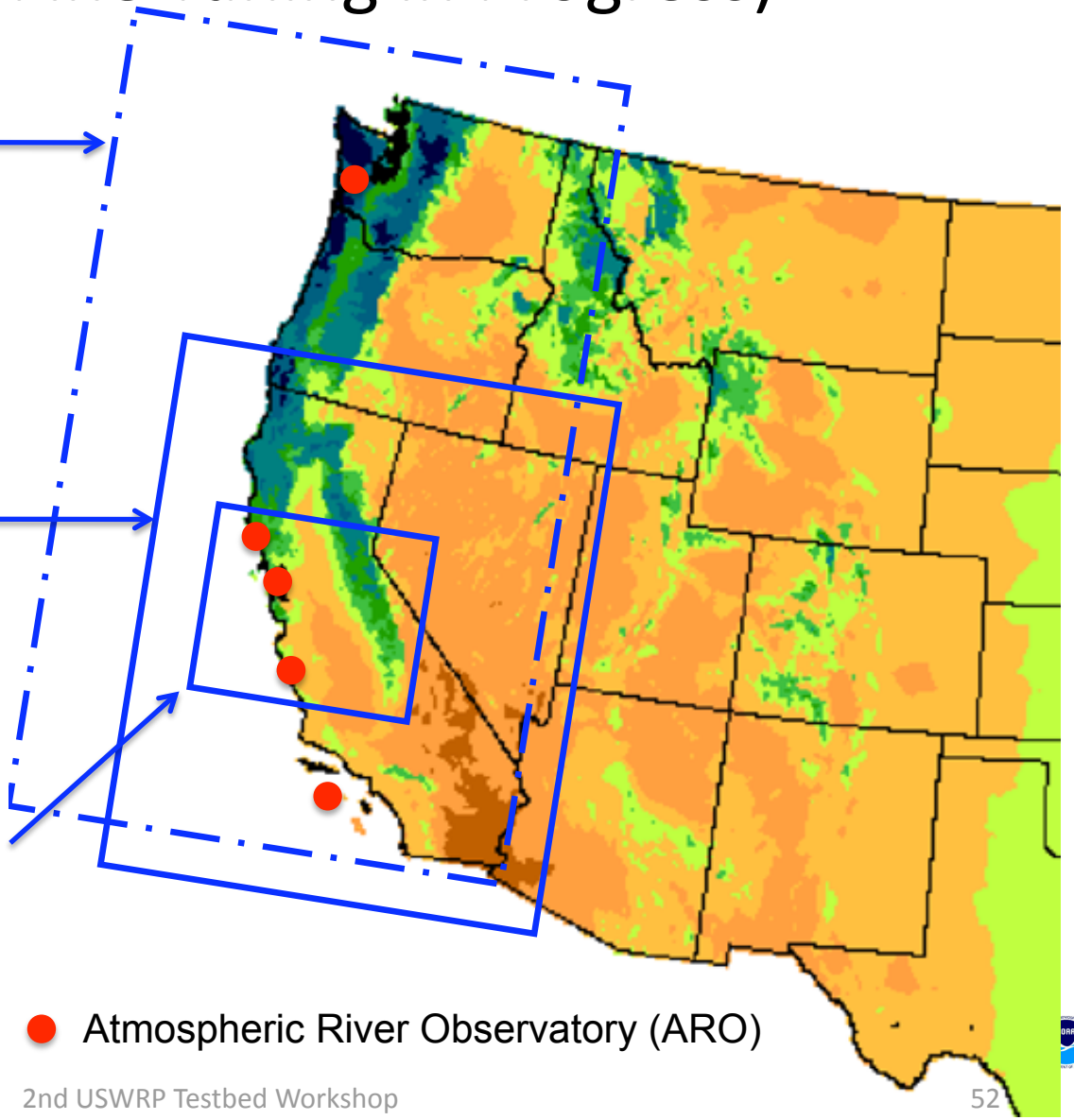
Streamlevel

Quantitative Precipitation Forecasting Timescales in HMT

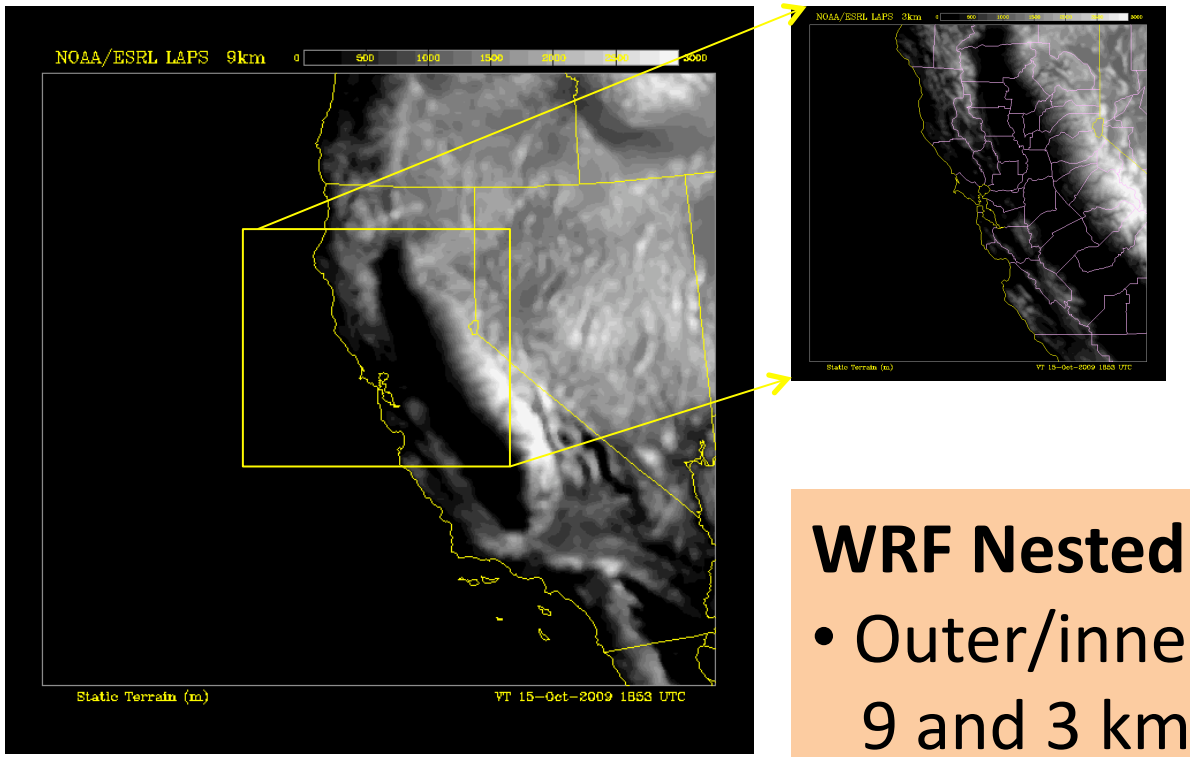


HMT-West 2010: WRF Ensemble Modeling Domains (Tentative; Fine Tuning in Progress)

- Single Deterministic Run for the *Atmospheric River Monitoring and Early Warning System*
  - 12 hour forecast; 1 hour updates
  - 10 km horizontal resolution
- 8-Member Ensemble Run for Probablistic Forecasts
  - 120 hour forecast; 6 hour updates
  - 9 km horizontal resolution
- 8-Member Super High-Resolution Ensemble Run for Probablistic Forecasts (nested)
  - 12 hour forecast; 6 hour updates
  - 3 km horizontal resolution



HMT-West EXPERIMENT DESIGN for 2009-2010



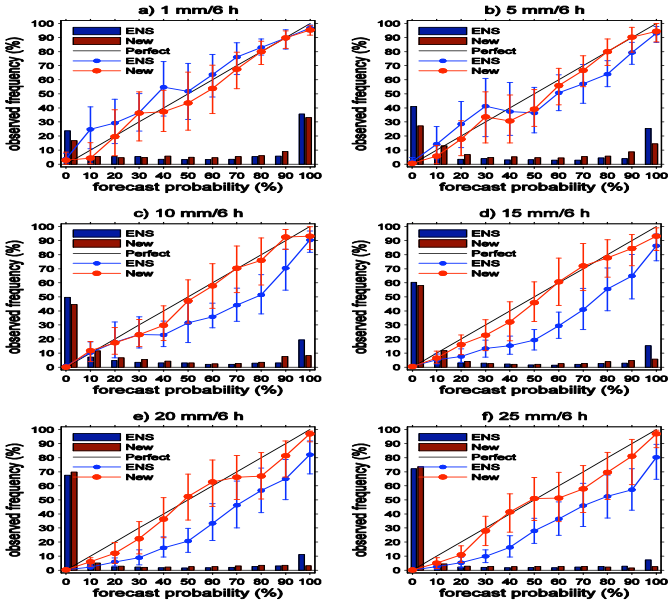
WRF Nested domain:

- Outer/inner nest grid spacing 9 and 3 km, respectively,
- 6-h cycles,
- Outer nest: 120 fcst hours,
- Inner nest: 12-h fcst hours.

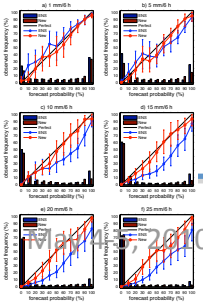
HMT-West ENSEMBLE DESIGN for 2009-2010

- 3 WRF-ARW RUNS AND 1 WRF-NMM RUN
  - WRF-ARW runs: Ferrier, Schultz, Thompson microphysics
  - WRF-NMM run: Ferrier microphysics
- 8 GFS ensemble members will provide LBCs for the mixed-model, mixed-physics ensemble
- One additional member will use WRF-ARW with Thompson microphysics and GFS deterministic run will provide LBCs,
- Time lagging optional
- The ensemble mean and probabilistic products will be displayed on ALPS


Calibration of PQPF (statistical post-processing)

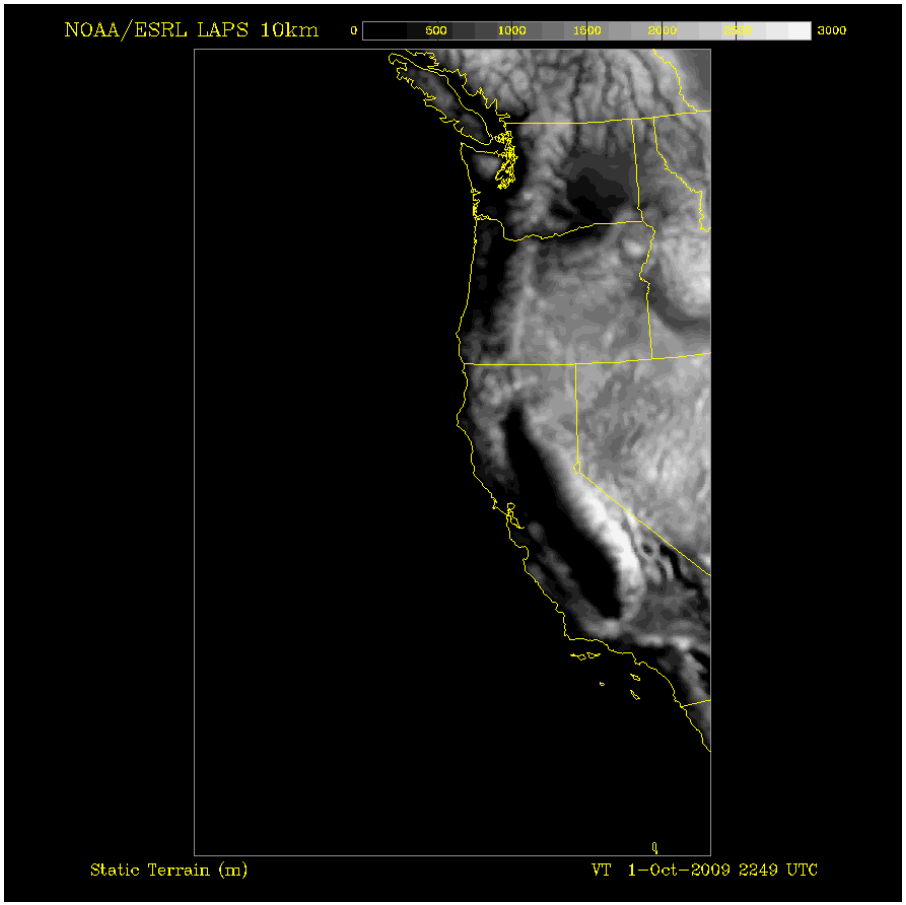


An example of probabilistic QPF (PQPF) calibration by using linear regression. The reliability notably improved after the calibration. Several IOPs were used for training purpose.



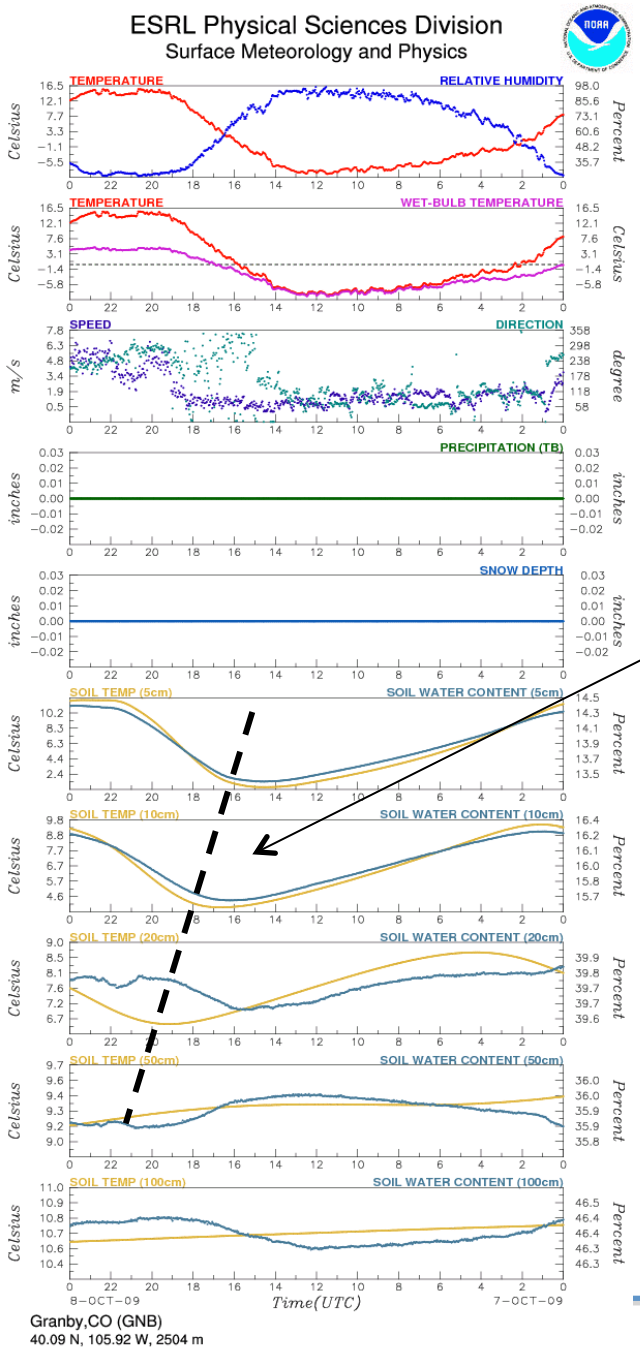
SEPARATE HIGH-RESOLUTION MODEL RUN FOR PSD's MOISTURE-FLUX FORECASTING TOOL for 2009-2010

- Domain extended further north and south compared to the ensemble domain
- 10 km horizontal grid spacing
- Hourly update
- 12-hr forecast
- LAPS initial conditions
- NAM LBCs
- HRRR profiles will be extracted



The PSD observations made in the Upper Colorado River Basin will support research and operations by providing information about soil moisture, soil temperature, snow depth, latent heat flux, sensible heat flux, net radiative flux, ground heat flux, wind speed, wind direction, surface pressure, temperature and relative humidity.

- Granby and Gunnison, CO selected for instrumentation
- Granby selected for snow sublimation studies
- Granby soil moisture probes along with standard surface meteorological instrumentation were installed and operational on10/2/09
- Granby eddy flux tower installation planned for May 2010.
- Gunnison soil station installation planned for June 2010
- CBRFC would like to validate NWS hydrological models using observations made in the Gunnison River Basin



Granby operational as of October 2, 2009

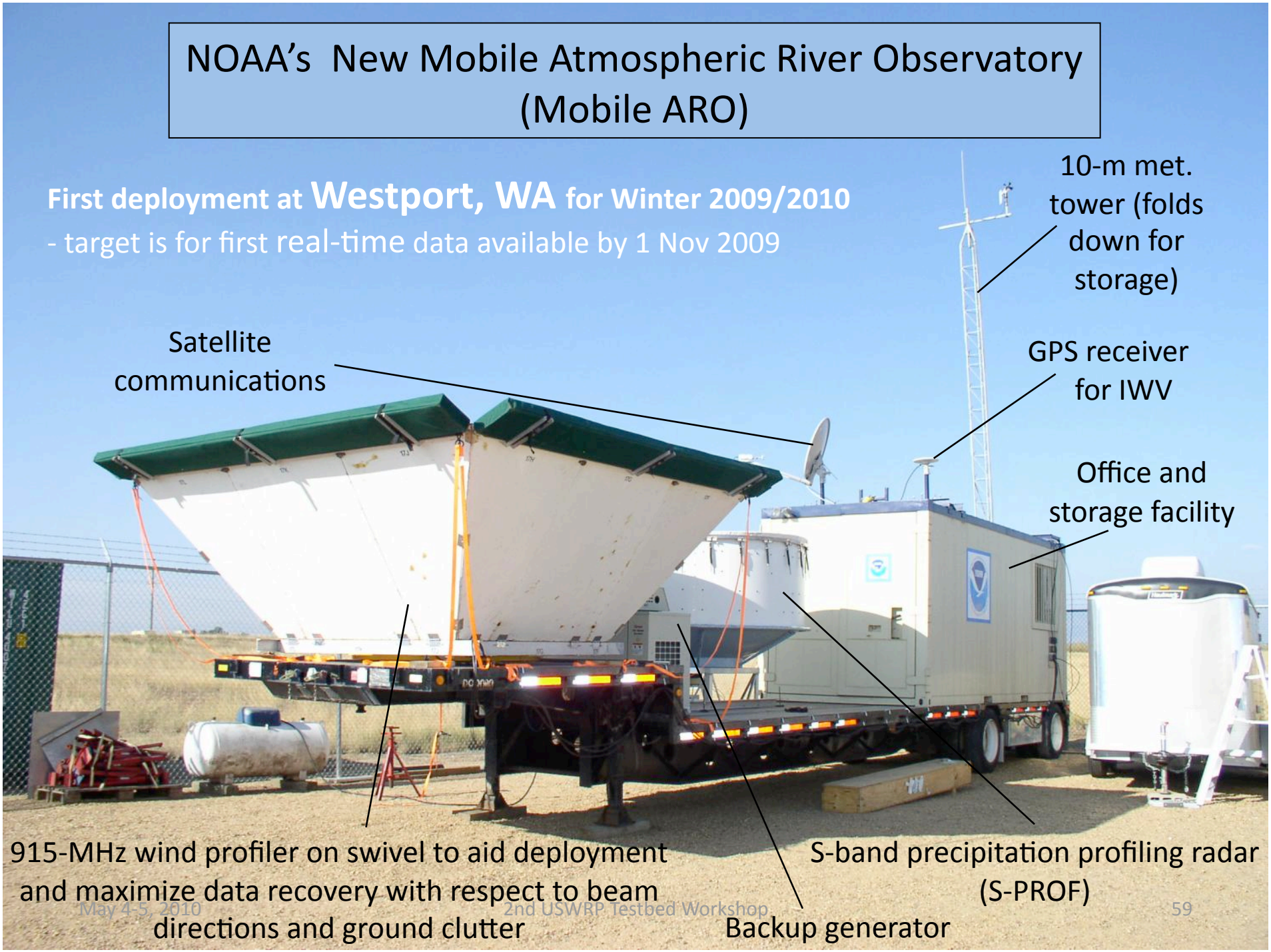
- Well defined diurnal heat wave in the soil
- Amplitude of the wave decreases with depth
- Soil moisture increases with depth

Data: http://www.esrl.noaa.gov/psd/data/obs

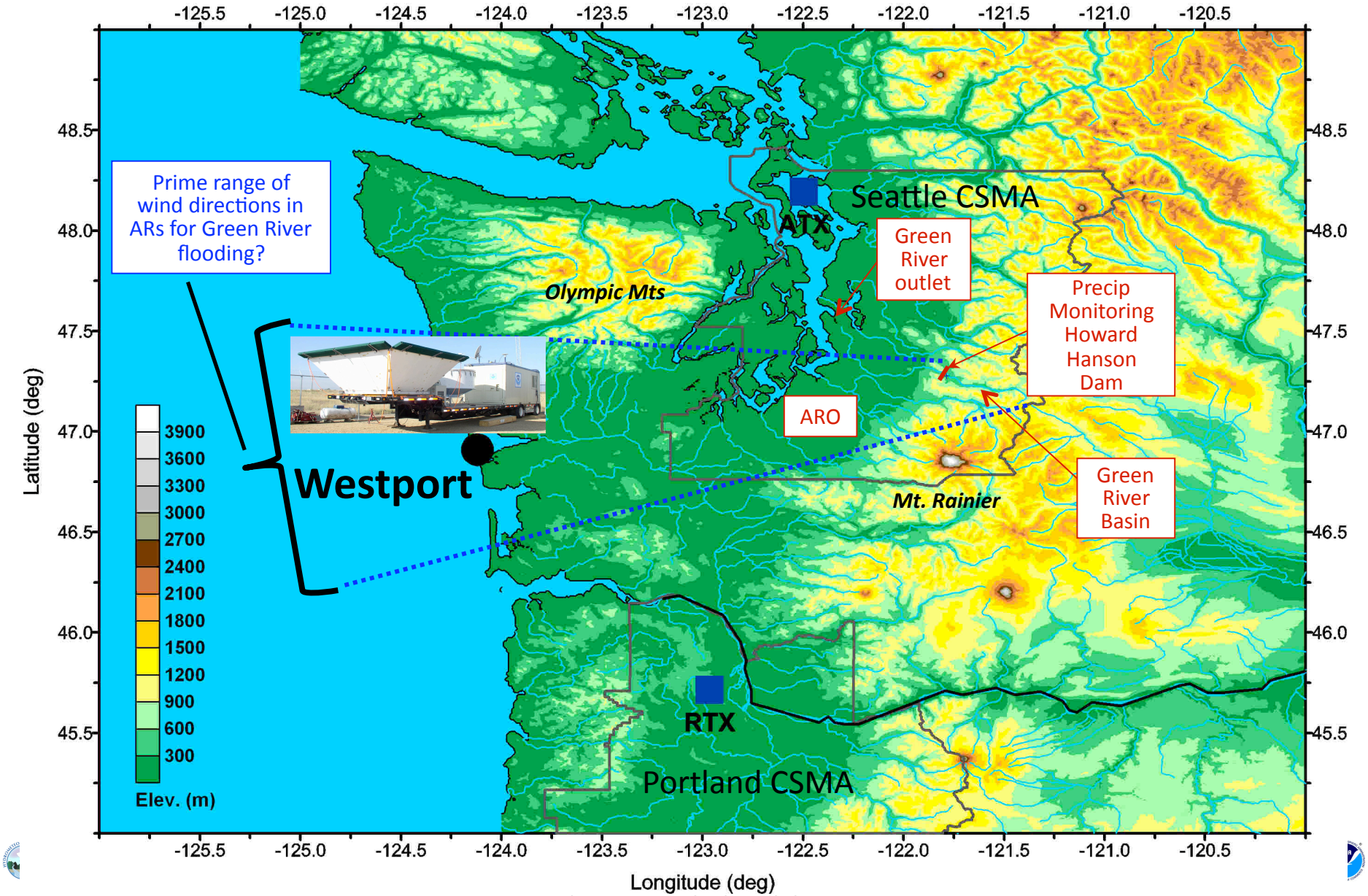
NOAA's New Mobile Atmospheric River Observatory (Mobile ARO)

First deployment at Westport, WA for Winter 2009/2010

- target is for first real-time data available by 1 Nov 2009



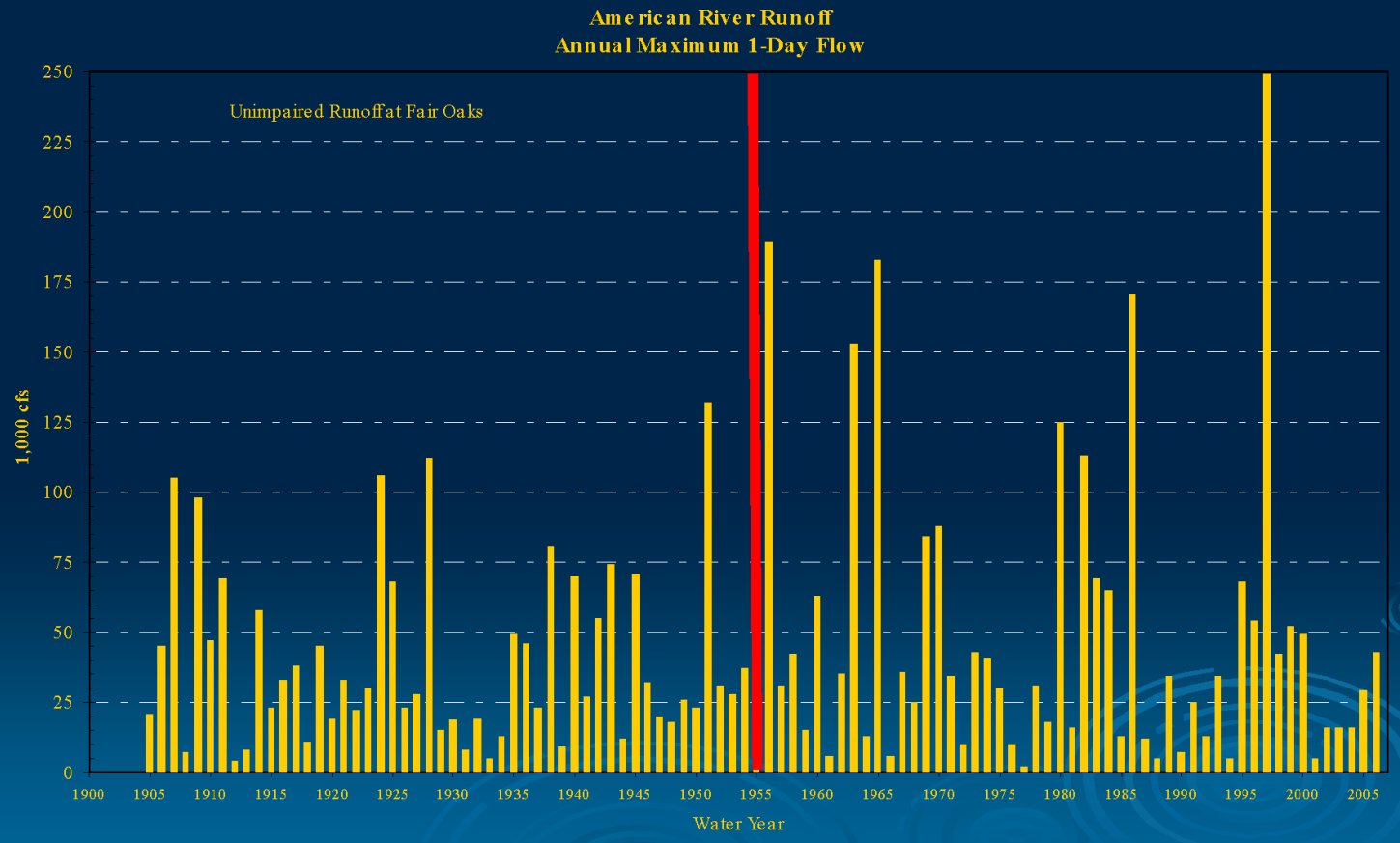
Washington Mobile Atmospheric River Monitoring System Deployment – 1 Nov/09



ARO Instrumentation and Measurements

Instrument	Measure(s)	Vertical Res.	Temporal Res.	Altitude Coverage
915-MHz Wind Profiler/RASS	Wind and Temperature Profiles, Snow Level, BL Depth	60 m, 100 m	Hourly or Sub-hourly	0.15-2+ km in clear air, 0.15-4+ km in storms (winds); 0.15-1+ km (Tv)
S-Band Precip. Profiling Radar (S=PROF)	Precipitation Reflectivity and Velocity Profiles, Snow Level	60 m	30-s	0.13-8+ km in storms
10-m Met Tower	P, T, RH, WS, WD, Solar IR., Net IR, Rainfall	N/A	2-min.	N/A
GPS Receiver	Integrated water vapor	N/A	Hourly or Sub-hourly	N/A
Optical Disdrometer	Velocity and Size Distributions of Precipitation	N/A	2-min.	N/A

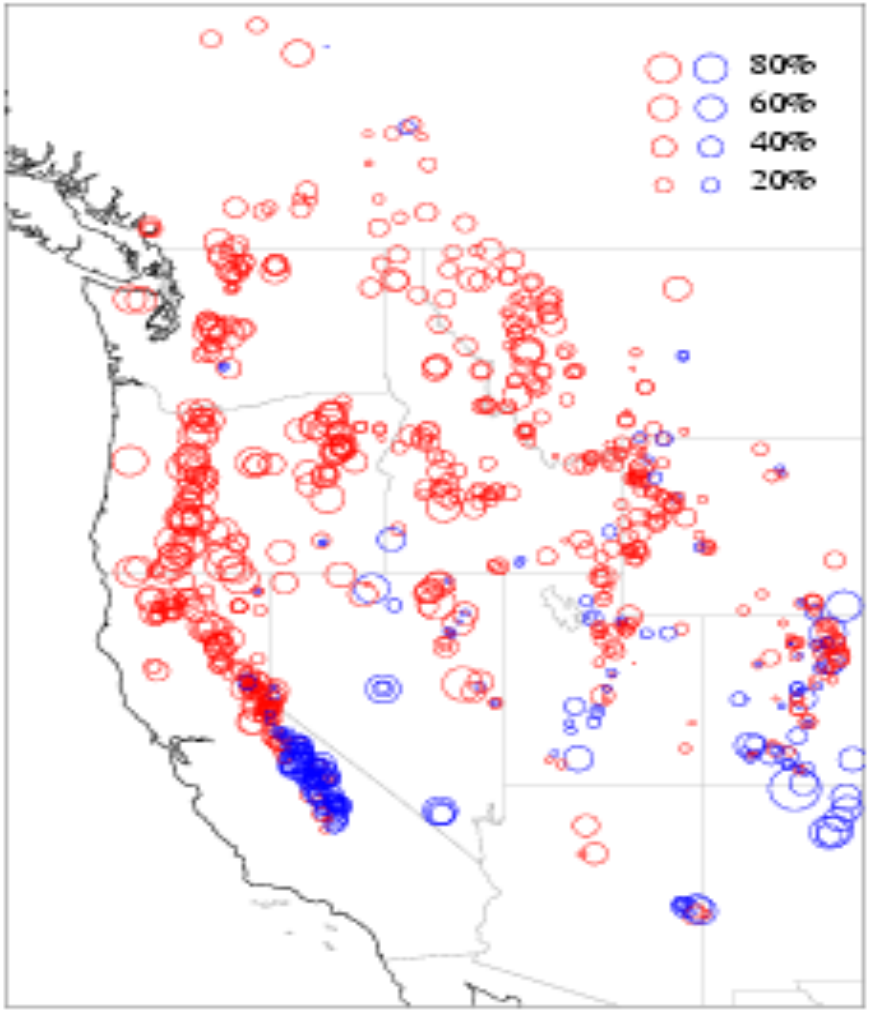

Changes in Peak Flows
American River



Red Line = Construction of Folsom Dam

Lester Snow, CA-DWR

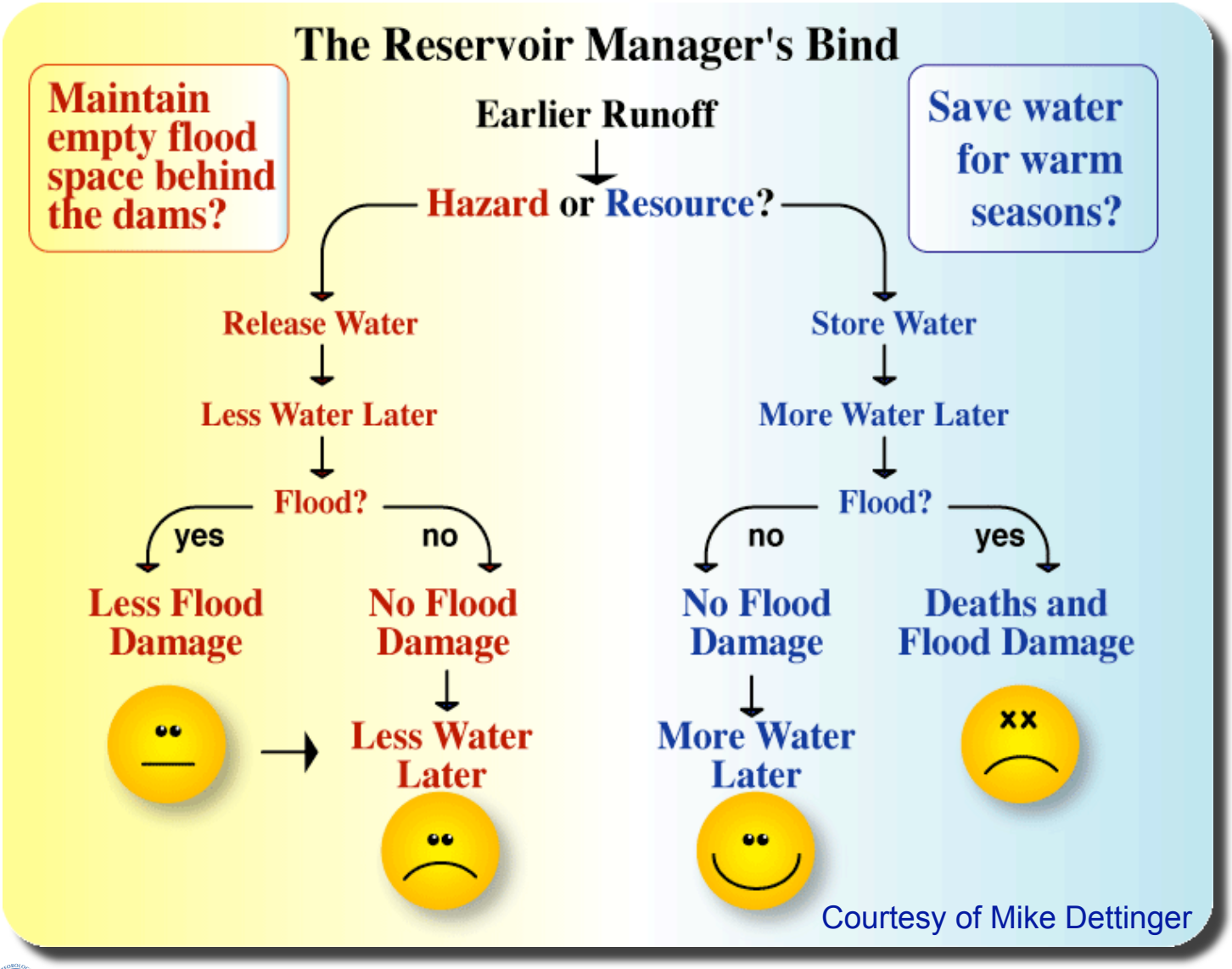
TRENDS (1950-97) in April 1 snow-water content at snow courses



- **Snowmelt supplies about 60-75% of western surface-water supplies, and a roughly equal (or greater) part of western ground-water recharge...**
- **Recent warming trends appear to have caused significant snowpack declines in much of that area**
- **--> Less spring snowpack**

Courtesy of Mike Dettinger

Climate change may put some water managers in a real bind!

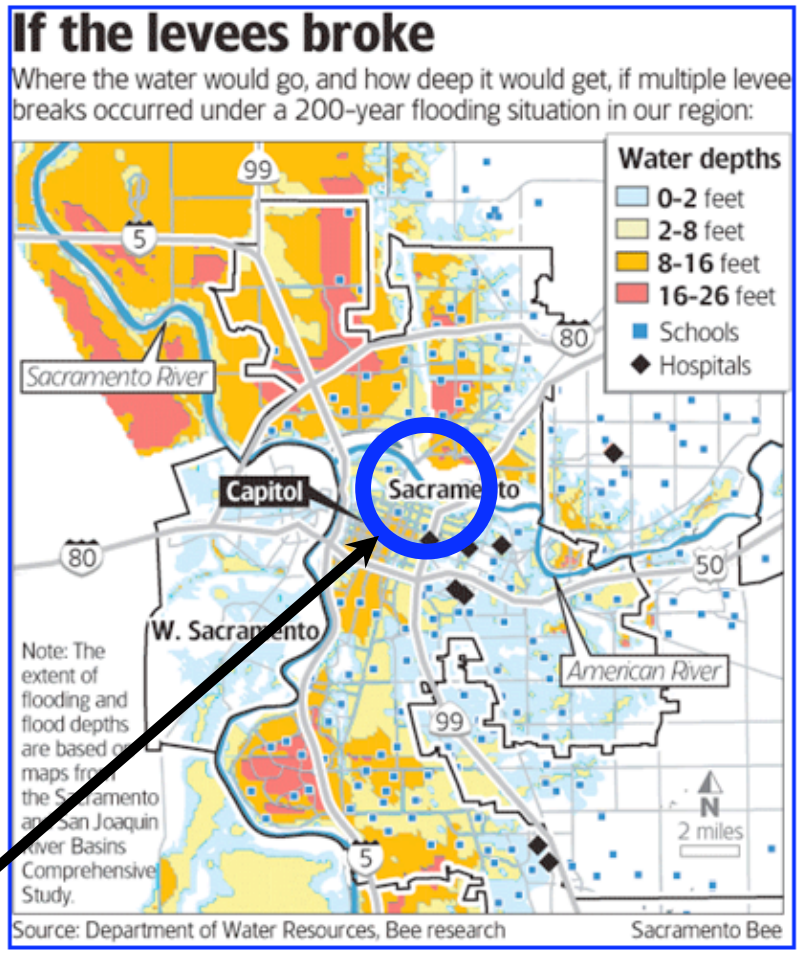


--> Storage & transferability of water supplies will thus be at a premium.

The Sacramento Flood Risk

- Complex water resource management issues in an urban area with large societal impacts
  - –Large demand for water/hydropower
  - –Threat of devastating flood

Photo by Bryan Patrick, Sacramento Bee



Several feet inundation possible in downtown Sacramento